Correlations, Value Factor Returns, and Growth Options*

Lorenzo Schönleber

This version: January 11, 2022

Abstract

This paper documents that the average equity market correlation is informative about the value of growth options and the correlation dynamics of growth and value stocks and, in turn, forecasts changes in growth options and the returns on the value factor. Consistently, a production-based asset-pricing model shows that correlations are homogeneous among stocks with similar growth characteristics and increasing in the value of growth options. Therefore, the expected average equity correlation serves as a leading procyclical state variable and drives the value premium. Correlations extracted from an equity value index improve the predictability of value-related factors in-sample and out-of-sample.

Keywords: option-implied correlations, value premium, present value of growth options, production model, factor return predictability, option-implied information, trading strategy, diversification, factor risk

JEL: G11, G12, G13, G17

*Lorenzo Schönleber is affiliated with the Collegio Carlo Alberto, Italy, lorenzo.schoenleber@carloalberto.org.
I received helpful comments and suggestions from Turan Bali, Alexander Barinov (discussant), Adrian Buss, Nicole Branger (discussant), Jens Christensen (discussant), Bernard Dumas (discussant), Ariel Gu (discussant), Kazuhiro Hiraki (discussant), Alexandre Jeanneret, Petter Kolm, Changjun Lee (discussant), Roberto Marfé, Chayawat Ornthanalai (discussant), Roberto Reno, Fabio Trojani, and Christian Wagner. I also thank participants at the Frankfurt School of Finance & Management Seminar, the 2nd QMUL Economics and Finance Workshop, the Second Asset Pricing Conference by LTI - Collegio Carlo Alberto, the PFMC 2019 - IPAG Business School, the University of St.Gallen, the Collegio Carlo Alberto, the NEOMA Business School, the VU Amsterdam, the NOVA SBE, the Alliance Manchester Business School, the Erasmus School of Economics, the HEC Montreal, the City University of Hong Kong, the 5th SDU Finance Workshop, the Southwestern Finance Association 2021, the AFFI 37th International Conference, the 17th Annual Conference of the Asia-Pacific Association of Derivatives, the Canadian Derivative Institute 2021 Conference, the 2021 FMA Annual Meeting, and the University of Verona, for useful comments. Special thanks goes to Grigory Vilkov for his unconditional support, stimulating discussions and helpful suggestions. All errors are mine.

Correlations, Value Factor Returns, and Growth Options

This version: January 11, 2022

Abstract

This paper documents that the average equity market correlation is informative about the value of growth options and the correlation dynamics of growth and value stocks and, in turn, forecasts changes in growth options and the returns on the value factor. Consistently, a production-based asset-pricing model shows that correlations are homogeneous among stocks with similar growth characteristics and increasing in the value of growth options. Therefore, the expected average equity correlation serves as a leading procyclical state variable and drives the value premium. Correlations extracted from an equity value index improve the predictability of value-related factors in-sample and out-of-sample.

Keywords: option-implied correlations, value premium, present value of growth options, production model, factor return predictability, option-implied information, trading strategy, diversification, factor risk

JEL: G11, G12, G13, G17

I. To-Do

- Outline IMC / IST - ask Papa regarding Z^{-1}
- Show rolling correlation of i) (IC/RC, IMC), ii) (PVGO Proxies, IMC), iii) (IC/RC, PVGO Proxies)
- Show not only correlation delta but rather correlation of the B/M portfolios. Ask Chay for B/M pic and plot (he has way higher absolut values)
- Redo OOS for HML
- Plot Z and IC for shocks in Z (model and empirical)

II. Introduction

It has long been recognized that the average equity market correlation (market-wide correlation) serves as an important state variable measuring the diversification benefits in financial markets. It predicts market returns and risks, and is, therefore, a variable of interest for investors. The correlation dynamics among stocks stems from a variety of sources, depending on other variables on the economic regime and the business cycle.

This paper introduces theoretically motivated empirical evidence that market-wide correlations are related to one of the most fundamental drivers of the economy, namely, economic growth. Market-wide correlations increase not only in market downturns, as documented in previous research, but also in anticipation of a good state due to an increase in individual growth options[1] and, hence, are related to the business cycle. The difference in returns between growth and value portfolios, namely, the returns on the value factor (the value premium) is known to be strongly associated to growth options. Consequently, growth and value portfolios differ not only in their average return but also in their time-varying correlation dynamics among themselves, which can be linked to the business cycle.

The interplay of market-wide correlations and growth options is also connected to returns on the value factor and market returns: Expected market-wide correlations and future valuations are positively related. Hence, when firms accumulate growth options, growth stocks comove more strongly with each other. Due to the accumulation of growth options, growth stocks will gain in value. The higher valuation of growth stocks compared to value stocks will result in a negative return on the value factor.[2]

My main results can be summarized as follows: i) An extension of the production-based asset-pricing model by Kogan and Papanikolaou (2014) shows that stock correlations are increasing in the firm's present value of growth options (PVGO), and, therefore, the average correlation among growth stocks and the average correlation among value stocks display a

[1] Growth options describe the opportunity to undertake positive net present value projects in the future.

[2] The high market capitalization among low book-to-market (B/M) stocks (growth stocks) contributes positively to this effect on a market level, and as another consequence, market returns will increase.

time-varying pattern in which the former exceeds the latter most of the time. Stock correlations are not only linked to the firms PVGO but also to firm-specific idiosyncratic components and, therefore, to the business cycle. The theory is consistent with the explored empirical evidence. ii) In the model, stock correlations are increasing in the firm's PVGO, and, therefore, empirically, expected market-wide correlations are related to growth characteristics and therefore predict the future changes in the market-wide PVGO positively. iii) The theoretical model and prior empirical results establish the value return predictability by expected market-wide correlations and provide an additional explanation of the already established market return predictability by expected market-wide correlations. iv) Market-wide correlations also predict other Fama and French (2015) value factors (such as CMA and RMW). Exploiting the more specific information content in expected correlations extracted for the S&P 500 Value Index improves the predictability results among value factors.

To obtain the aforementioned results, I proceed as follows. The main theoretical motivation for the paper is the structural model developed by Kogan and Papanikolaou (2014), in which investment-specific technology shocks (IST) affect the value of assets in place (VAP) and the PVGO. As a result, the firms' PVGO can be treated as a systematic component affecting the expected stock return negatively and, therefore, giving rise to the value premium. While Kogan and Papanikolaou (2014) focus on the cross-section, I build on their framework and formally work out economic mechanisms to explicitly study the expression for the correlation among stocks as a function of growth characteristics. The model confirms a stronger comovement among growth stocks compared to value stocks. In line with the theory, I empirically document that the correlation of growth stocks is on average higher than that of value stocks and that the difference between the two quantities is time-varying and moves with the state of the economy.

While the prior result purely investigates the correlation dynamics, the theoretical finding that the correlation between stocks is a function of the firm's PVGO motivates the relation between expected market-wide correlations and (future) changes in the economies growth characteristics, that is, changes in the market-wide PVGO. The anticipation of a future increase in individual firm PVGOs is reflected in an increase in the expected market-wide correlation extracted from a large index such as the S&P 500, estimated from option data.

The explored link between (firm) characteristics and market-wide correlations leads to the question of whether these insights can be applied to explain portfolio returns based on growth and value characteristics. The theoretical model motivates me to analyze the closed-form expressions for the firms' expected returns, which are negatively related to the PVGO, giving rise to the value premium. Therefore, if expected market-wide correlations can predict changes in one of the models' state variable (PVGO), it is natural that the ability to predict the associated value factor returns inherits.

Empirically, I document the predictive power of expected market-wide correlations with respect to the value factor. In univariate regressions, expected market-wide correlations, extracted from options data, predict future returns for horizons of up to one year. The regression coefficient is significantly negative, and its predictive power, measured in terms of R^2, is increasing from about 2.6% at the monthly horizon to around 22% on a yearly horizon.[3] By analyzing the individual long and short legs of the HML factor, it turns out that the predictive power of expected market-wide correlations is stronger for returns on growth stocks (L). In the last step, since the HML factor also considers the size of the firm, I emphasize the predictability of returns on growth and value stocks considering only the firm's B/M. Predictive regressions for each decile portfolio sorted on B/M from growth (low B/M) to value (high B/M) show that with increasing decile, the R^2s are decreasing, confirming that the predictive power of expected market-wide correlations is concentrated among growth stocks.

Overall, the empirical results are robust to various specifications, including the usage of realized correlations over longer time horizons, non-overlapping sampling, the sample split according to the NBER recession indicator, and controlling for other known predictor variables. It is worth mentioning that expected market-wide correlation outperforms realized market-wide

[3] In order to verify that the return predictability of the value factor is not driven by the market return predictability, I construct a market-neutral version of the HML factor (HML*), where the "pure" value premium is also predicted significantly negative.

correlation in terms of R^2s, confirming the information advantage of an option-implied variable over its realized equivalent.

The model-implied idiosyncratic variance allows me to investigate the influence of idiosyncratic growth components on the correlation between stocks. In the model, the correlation between stocks serves as the connection between the firms' systematic and idiosyncratic growth components. The gathered theoretical insights and the empirical evidence connecting market-wide correlations to the dynamics of growth options, and systematic and idiosyncratic risks, indicate that expected correlation serves as a leading procyclical state variable.

Expected market-wide correlation predicts the returns of the value factor (HML) and its components. The prediction of the additional Fama and French (2015) value factors, such as CMA and RMW, is extended, considering the expected market-wide correlation for the S&P 500, and expected correlations extracted for the S&P 500 Value Index, in-sample and out-of-sample.[4] Interestingly, even though the S&P 500 Value Index contains only about half the stocks as the S&P 500 parent index, the predictability results for the value factors are similar (or sometimes even superior), as if considering expected market-wide correlations extracted for the whole S&P 500. Therefore, it seems important to compute the correlation of the stocks of interest, instead of considering as many stocks as possible.

III. Literature Review

This work is related to the literature dealing with theoretical models explaining the returns on the value premium and other asset pricing anomalies. Zhang (2005) shows, due to costly reversibility, that value firms are less flexible in cutting capital, causing them to be riskier than growth firms. According to Garleanu, Kogan, and Panageas (2012), growth firms offer a hedge against displacement risk, which describes the process of innovation capturing that the young benefit more from innovative activity than the old. Berk, Green, and Naik (1999) provide a theoretical model showing that stock returns are related to the market value and to book-to-

[4]One can find the S&P 500 Value Index under the ticker "SVX" or "IVE" (iShares S&P 500 Value ETF).

market, serving as a state variable summarizing the firms' risk. Kogan and Papanikolaou (2013) argue that firm characteristics are likely correlated within firms' exposure to the same common risk factor, which is not captured by the market. Gomes, Kogan, and Zhang (2003) develop a general equilibrium model that links expected stock returns to firm characteristics, such as size, book value, investment, and productivity.

Growth options have different risk characteristics than assets in place, and, therefore, also different exposure to systematic risk, measured by the firms' market beta. In the model of Santos and Veronesi (2004), the equity risk premium is low when the dispersion in systematic risk is high. Within their model they fully characterize conditional betas as a function of fundamentals and the aggregate market premium. Petkova and Zhang (2005) decompose market betas into value and growth betas, and find that the value premium displays a countercyclical pattern of risk, and that value (growth) betas tend to covary positively (negatively) with the future market risk premium. Closely related to the market beta dispersion is the cross-sectional return dispersion (RD). In Stivers and Sun (2010) and Angelidis, Sakkas, and Tessaromatis (2015), the authors find that RD is positively related to the subsequent value premium and negatively related to the aggregated equity premium. Therefore, RD serves as a leading countercyclical state variable.

This paper also adds the role of market-wide correlation to the strands of literature dealing with idiosyncratic risk, which is known to be connected to the market risk premium, the value premium, growth options, and the business cycle. Campbell, Lettau, Malkiel, and Xu (2001) and Irvine and Pontiff (2009) show empirically an increase in firm-level volatility relative to the market volatility accompanied by a lower average correlation. The latter paper claims that increased competition between firms induces a lower correlation between firms' performance and cash flows, and, therefore, more idiosyncratic risk. Guo and Savickas (2008) argue that changes in average idiosyncratic volatility provides a proxy for changes in the investment opportunity set, which is closely related to the book-to-market factor. An investigation of idiosyncratic market-wide risk and the connection to growth options can be found in Cao, Simin, and Zhao (2008), in which the authors establish a positive relation between the two variables.

Since this paper is also about predictability, I contribute to a strand of literature that uses several macro- and market-based variables to predict returns. Gulen, Xing, and Zhang (2010) study the time-variations of the value premium using a two-state Markov switching frame with time-varying transition probabilities. Asness, Friedman, and Liew (2000) predict annual value strategy returns formed by incorporating and composing three accounting ratios, such as earnings, book value, and sales, via their corresponding spreads. Bollerslev, Todorov, and Xu (2015) predict the value premium in-sample via their left risk-neutral jump tail variation measure, in which the maximal R^2 is obtained around a four month predictive horizon.

This paper exploits the information content of market-wide correlations, which can be extracted backward-looking from historical returns (realized correlations), or forward-looking via option data (expected correlations or implied correlations). In Pollet and Wilson (2010), long-term market returns, that is, quarterly stock market excess returns, are predicted by realized correlations. Several studies within the field of option-implied information deal with implied correlations, which quantify the expected diversification benefits. Driessen, Maenhout, and Vilkov (2005) and Driessen, Maenhout, and Vilkov (2009) demonstrate that implied correlations predict market returns for horizons up to 12 months. In Buss, Schoenleber, and Vilkov (2018), the authors decompose implied correlation in its option-implied parts (market variance, average idiosyncratic variance, and cross-sectional dispersion of market betas) and analyze the different information content and predictability horizons of these in the scope of market and risk predictability. A good overview about the option-implied predictive literature can be found in Christoffersen, Jacobs, and Chang (2011). To my knowledge, all of these studies explore the relation of market-wide correlations and the return predictability of stock returns on an aggregate market level (S&P 500, S&P 100, or the DJ 30) and not on factors related to growth, value, or the value premium.

The rest of this paper is organized as follows: Section IV states the production model. Section V shows how to construct the correlation measures. Section VI empirically tests the models main implications. Section VII emphasizes the role of implied correlation as a procyclical state variable. In Section VIII, the value predictability is extended to other factors, out-of-sample, and regarding other implied correlation measures. Section IX provides robustness tests. Section X concludes.

IV. The Model

The production model by Kogan and Papanikolaou (2014) explains the effect of investment-specific technology shocks (IST) on the cross-sectional differences in risk premia, that is, to the firms value of assets in place (VAP) and the value of growth opportunities (PVGO). Their major theoretical insight is that the returns of growth firms, which benefit the most from positive IST shocks, have higher exposure to IST shocks, and, therefore, on average a lower return.

While taking the general setting such as the quantity and the form of the state variables as given, in this presented extension, new interesting elements of the model that are in line with the data are studied. The explicit expression of the correlation between two firms is connected to PVGO and differentiated from the index variance through the model-implied idiosyncratic variance. The model implications further support the empirical results associated with the interplay between market returns, the value premium, and market-wide correlations, presented later in the paper. Within the next sections the main equations of the model are stated and derived; for details, see the original paper or the Internet Appendix C.

A. Model Setup

The state variables capturing firm-specific (ε_{ft}), project-specific (u_{jt}), economy-wide shocks (x_t), and the cost of capital (z_t) evolve according to

$$d\varepsilon_{ft} = -\theta_\varepsilon(\varepsilon_{ft} - 1)dt + \sigma_\varepsilon\sqrt{\varepsilon_{ft}}dB_{ft}, \tag{1}$$

$$du_{jt} = -\theta_u(u_{jt} - 1)dt + \sigma_u\sqrt{u_{ft}}dB_{jt}, \tag{2}$$

$$dx_t = \mu_x x_t dt + \sigma_x x_t dB_{xt}, \tag{3}$$

$$dz_t = \mu_z z_t dt + \sigma_z z_t dB_{zt}, \tag{4}$$

where the Brownian motions dB_{ft}, dB_{jt}, dB_{xt}, and dB_{zt} are pairwise independent. The stochastic discount factor prices the risk associated with x and z,

$$\frac{d\pi_t}{\pi_t} = -rdt - \gamma_x dB_{xt} - \gamma_z dB_{zt}. \tag{5}$$

B. Assets in Place, Investment, and Valuation

Each firm f owns a finite number of individual projects J_t^f, which they create over time through investment. Given the projects' chosen physical capital K_j, the output of an individual project j equals

$$y_{fjt} = \varepsilon_{ft} u_{jt} x_t K_j^{\alpha}, \tag{6}$$

where K_j denotes the chosen project physical capital.

Firms acquire new projects according to a Poisson process with firm-specific arrival rate $\lambda_{ft} = \lambda_f \tilde{\lambda}_{ft}$, thereby $\tilde{\lambda}_{ft}$ follows a two-state Markov process where a firm is either high growth λ_H or low growth λ_L.[5] Firms' investment decisions are affected by the trade-off between the market value of a new project and the cost of physical capital associated with it. Hence, the firms' market value of an existing project is equal to the expected present value of its cash flows.[6]

The value of the firm (V) can be composed as the present value of cash flows generated by existing project (VAP) and the expected discounted NPV of future investments (PVGO) (see (C1), (C3), (C4) for details),

$$VAP_{ft} = \sum_{j \in J_t^f} p(\varepsilon_{ft}, u_{jt}, x_t, K_j) = x_t \sum_{j \in J_t^f} A(\varepsilon_{ft}, u_{jt}) K_j^{\alpha} =: x_t \sum_j A_{ft}, \tag{7}$$

[5]The distribution of mean project arrival rates equals $\mathrm{E}[\lambda_{ft}] = \lambda_f = \mu_\lambda \delta - \sigma_\lambda \delta \log(X_f)$, where $X_f \sim U[0,1]$.

[6]The firm chose K^* such that it maximizes the NPV, which is the difference between the present value of its cash flows and the associated costs of capital $z_t^{-1} x_t K_j$ (see (C2)).

$$PVGO_{ft} = z_t^{\frac{\alpha}{1-\alpha}} x_t G(\varepsilon_{ft}, \lambda_{ft}) =: z_t^{\frac{\alpha}{1-\alpha}} x_t G_{ft}, \tag{8}$$

$$V_{ft} = VAP_{ft} + PVGO_{ft} = x_t \sum_j A_{ft} + z_t^{\frac{\alpha}{1-\alpha}} x_t G_{ft}. \tag{9}$$

C. Risk and Risk Premia

The expected excess return of firm f is (see (C12))

$$\frac{1}{dt} E[R_{ft}] - r_f = \gamma_x \sigma_x + \frac{\alpha}{1-\alpha} \gamma_z \sigma_z \frac{PVGO_{ft}}{V_{ft}}. \tag{10}$$

Kogan and Papanikolaou (2014) argue that the price of risk for disembodied technology shocks γ_x is positive, while the price of risk for IST shock γ_z is negative.[7] This serves as an explanation for the outperformance of value firms compared to growth firms and introduces an additional systematic factor in the firms' return structure. Since market-to-book ratios are positively (negatively) correlated with the share of growth opportunities to firm value ($PVGO/V$), growth (value) firms are more strongly linked to the correction in returns.

[FIXME: LS# 1: Important message] [FIXME: LS# 2: Emphasize the correlation between IMC and PVGO]

To obtain expressions for the aggregate (expected) market return, the results for the individual firms are exploited. Value-weighting (10) across its constituents results in the expected market excess return and is given by (see (C13))

$$\frac{1}{dt} E[R_{Mt}] - r_f = \gamma_x \sigma_x + \frac{\alpha}{1-\alpha} \gamma_z \sigma_z \frac{PVGO_{Mt}}{V_{Mt}}, \tag{11}$$

where $\frac{PVGO_{Mt}}{V_{Mt}}$ denotes the market-cap-weighted averaged individual firm ratios $\frac{PVGO_{ft}}{V_{ft}}$.[8]

[7] Empirically, the authors use the relative stock returns of the investment and consumption good producers to create a factor-mimicking portfolio (IMC) for the IST shock, which is long the investment sector and short the consumption sector. Sorting firms on their IST betas results in a declining profile of average stock returns and an increasing profile of market betas. Hence, IST shocks carry a negative risk premium. Papanikolaou (2011) provides a theoretical explanation for the negative price of risk of IST.

[8] It is assumed that γ_x, σ_x, α and γ_z are equal for each firm.

D. Firm Return Dynamics

In order to analyze higher moments of firms, and between firms, the firms instantaneous return dynamics are derive first, which can be expressed as (see (C15) and (C17))

$$dR_{ft} = \frac{dV_{ft}}{V_{ft}} = \mathrm{E}[R_{ft}]dt + \sigma_x dB_{xt} + \frac{\alpha}{1-\alpha}\frac{PVGO_{ft}}{V_{ft}}\sigma_z dB_{zt} + \frac{dIdio_f}{V_{ft}}, \tag{12}$$

where $dIdio_f$ denotes the dynamics associated to A_{ft} (as a function of ε_{ft}, u_{jt}, and K_j^α) and G_{ft} (as a function of ε_{ft}, and λ_{ft}). The covariance and the variance of the returns can be calculated as (see (C18) and (C19))

$$dR_{kt}dR_{lt} = \sigma_x^2 dt + (\frac{\alpha}{1-\alpha})^2\sigma_z^2 \frac{PVGO_{kt}}{V_{kt}}\frac{PVGO_{lt}}{V_{lt}}dt, \tag{13}$$

$$\sigma^2(dR_{ft}) = dR_{ft}dR_{ft} = \sigma_x^2 dt + (\frac{\alpha}{1-\alpha})^2\sigma_z^2(\frac{PVGO_{ft}}{V_{ft}})^2 dt + (\frac{dIdio_f}{V_{ft}})^2. \tag{14}$$

Idiosyncratic terms are uncorrelated, and, hence, the covariance is increasing in the PVGO, depending on α and the volatility of the cost of capital process σ_z. To calculate the correlation, one normalizes the covariance by the standard deviations of the respective processes (C20),

$$Corr(dR_{kt}, dR_{lt}) = \frac{\sigma_x^2 dt + (\frac{\alpha}{1-\alpha})^2\sigma_z^2\frac{PVGO_{kt}}{V_{kt}}\frac{PVGO_{lt}}{V_{lt}}dt}{\sqrt{\sigma_x^2 dt + (\frac{\alpha}{1-\alpha})^2\sigma_z^2(\frac{PVGO_{kt}}{V_{kt}})^2 dt + (\frac{dIdio_k}{V_{kt}})^2}\sqrt{\sigma_x^2 dt + (\frac{\alpha}{1-\alpha})^2\sigma_z^2(\frac{PVGO_{lt}}{V_{lt}})^2 dt + (\frac{dIdio_l}{V_{lt}})^2}}. \tag{15}$$

Therefore, the correlation among firms captures the individual PVGOs such as the idiosyncratic dynamics of the firms. In Figure 11 the correlation (15) is depicted as a function of the firms' PVGOs and for different idiosyncratic levels (Panel A – Panel D). As visible, the correlation between two firms is an increasing function of the firms individual PVGO. This is why, for any given level of idiosyncratic risk (Figure 11 Panel A to Panel D), the correlation among growth firms exceeds the correlation among value firms. This can be inferred immediately from comparing the boundaries of the plots, that is, for individual PVGOs close to 1 (growth firms) or close to 0 (value firms).

The level of correlation between any two firms is decreasing in the firms idiosyncratic growth components. To further improve the understanding of the result, the idiosyncratic component dynamics of the firm (C16),

$$dIdio_f = x_t d \sum_{j \in J_t^f} A(\varepsilon_{ft}, u_{jt}) K_j^{\alpha} + z_t^{\frac{\alpha}{1-\alpha}} x_t dG(\varepsilon_{ft}, \lambda_{ft}), \tag{16}$$

are analyzed next. The first part corresponds to changes in $A(\varepsilon_{ft}, u_{jt})$, which is a function of the firm-specific component ε_{ft}, and the project-specific component u_{jt} and is, therefore, directly associated with the (change) of assets in place (see (C1) and (C5)). For the second part, as inferable from (C4), $G(\varepsilon_{ft}, \lambda_{ft})$ is a function of the returns to scale at the project level α, the firm-specific component ε_{ft} (such as managerial skill, that is, the "success rate" of the project), and the individual firms' arrival rate of the project λ_{ft}. $G(\varepsilon_{ft}, \lambda_{ft})$, therefore, combines the success of the project with the average project arrival rate of the firm. Taking the two expressions together, a high level of idiosyncratic variance corresponds to positive changes in the project-specific components, a high success of the project, and a high project arrival rate.

Contrasting the expression for $PVGO_{ft}$ (8), and as just outlined, the idiosyncratic component $dIdio_{ft}$ (16), there are several differences immediately visible. First, the expression for the project-specific component u_{jt} is not part of the expression for $PVGO_{ft}$. Second, $PVGO_{ft}$ is a function of G_{ft}, whose level is heavily determined by the two growth states of the firm ($\tilde{\lambda}_{ft} \in [\lambda_H, \lambda_L]$). In contrast, $dIdio_{ft}$ as a function of the changes in G_{ft} (dG_{ft}), does not rely heavily on the state itself.

Overall, the correlation between firms is effected by the proportion of systematic growth as opposed to idiosyncratic growth, where the two main drivers are identified to be the project-specific component u_{jt}, and the systematic growth component of the firm $\tilde{\lambda}_{ft}$. In Section VII market-wide correlation will be connected to state variables know or be associated with systematic and idiosyncratic risk, and in a next step to growth options, market returns and the value premium.

To conclude this section, the main predictions of the model, which will later be tested empirically, are restated: i) The correlation among growth firms exceeds the correlation among value firms. These dynamics are time-varying. ii) Correlation is a function of the firms PVGO and, therefore, expected correlations should be related to future movements in PVGO measures. iii) An average market-wide increase in PVGO gives rise to the value premium (10) and reduces the expected market returns (11). Therefore, variables linked to PVGO should predict returns on the value factor and market returns.

Before the empirical testing of the model implications is conducted, availability, preparation, and the construction of the variables is explained in the next section.

E. The Model Simulation

V. Data and Preparation of Variables

Expected market-wide correlations, that is, option-implied equicorrelations, are estimated, following Driessen, Maenhout, and Vilkov (2005), from the restriction that the variance of the index I has to be equal to the variance of the portfolio of its constituents (which holds under both—objective and risk-neutral—measures). Given the variances of the index $\sigma_I^2(t)$, its components $\sigma_i^2(t), i = 1 \ldots N$, and the index weights $w_i(t)$, the equicorrelation $\rho_{ij}(t) = \rho(t)$ is calculated as

$$\rho(t) = \frac{\sigma_I^2(t) - \sum\limits_{i=1}^{N} w_i(t)^2 \sigma_i^2(t)}{\sum\limits_{i=1}^{N} \sum_{j \neq i} w_i(t) w_j(t) \sigma_i(t) \sigma_j(t)}. \tag{17}$$

When using risk-neutral implied (realized) variances and volatilities in (17), one calculates then implied (realized) correlations — IC (RC). The composition of all the indices is obtained from Compustat, while the data on returns and market capitalization is received from CRSP.[9]

Computing the option-based variables relies on the Surface File from OptionMetrics, selecting for each underlying options with 30, 91, 182, 273, and 365 days to maturity and (absolute) delta lower or equal to 0.5.[10] Option-implied second moments are computed as simple

[9]Merging CRSP with Compustat is done via the CCM Linking Table using GVKEY and IID to link to PERMNO, following the second-best method from Dobelman, Kang, and Park (2014).

[10]Matching the historical data with options happens through the historical CUSIP link provided by OptionMetrics. PERMNO is used as the main identifier in the merged database.

variance swaps following Martin (2013). The options for the S&P 500 are available from January 1996 through December 2017, while for the S&P 500 Value Index the availability starts in August 2006.[11] In Table I the summary statistics for realized and implied correlations are presented while the time series are displayed in Figure 1.

The portfolio return data is available over the whole sample period on Kenneth French's website. The market-neutral version of the Fama and French factor is obtained by regressing, for each point in time, the considered value factor on a constant and the market return over a window of 21 business days, as follows

$$HML_{t-21\to t} = \alpha + \beta_{MKTRF} MKTRF_{t-21\to t} + \varepsilon_t. \tag{18}$$

$\alpha + \varepsilon_t$ are then considered as the market-neutral return of the factor (called HML^*). Table II Panel A, displays the correlation of the value factors from 1965 to 2018 sampled on a monthly frequency. The value factor is negatively correlated with the market (-0.26), in contrast, the corresponding legs of the factor are highly positively correlated with the market (0.89 for H and 0.95 for L). For the market-neutral value factor HML^*, the correlation with the market displays lower values (per construction). In Panel B, the correlation between the market (value factors), and the B/M sorted decile portfolios is displayed, which is higher (lower) for low B/M portfolios.

The present value of growth options is defined as the present value of dividends from all firms' projects to be adopted in the future and can be calculated as the difference between the aggregate market value and the value of assets in place. Several variables associated with the present value of growth options are constructed, as in Cao, Simin, and Zhao (2008) on the firm level: i) The Market-to-Book Ratio (M/B) proxies for corporate growth options due the incorporation of the market value of assets ii) Tobin's Q is the ratio between the physical asset market value and its replacement value. iii) The Debt to Equity ratio (DTE) represents growth options, since firms with significant growth opportunities may have lower financial leverage

[11] The traded continuum of index options on the SVX, i.e., the S&P 500 Value Index, is sometimes limited, and the change in the associated implied index variance can be quite large. To overcome the fluctuation, the simple variance swaps are averaged over a rolling window of five trading days.

(lower DTE).[12] iv) $CAPEX$ acts as a proxy for growth options since capital expenditures lead to new investment opportunities. In the empirical tests, I follow insights from Cao, Simin, and Zhao (2008) to obtain the value-weighted firm averages for M/B, Q, DTE, and $CAPEX$. Details on the calculation can be found in Appendix A. The summary statistics for the value of growth options proxies are displayed in Table III.

A number of realized portfolio risk measures over a particular future horizon of 30, 91, 182, 273, and 365 days are prepared: The cross-sectional dispersion of market betas ($\sigma^2(\beta_M)$) for the available CRSP universe, quantifying portfolio risks — calculated as the cross-sectional variance of the market betas (which are obtained for each stock in the sample over the required future period from a factor model[13]).[14] The residuals from the just outlined regressions are considered for the calculation of the sum of squared residuals (SSR) at each point in time.[15] Value and growth betas are calculated as in Petkova and Zhang (2005), where value and growth portfolio excess returns ($H - r_f$ and $L - r_f$) are regressed on the market excess return ($MKTRF$). The return dispersion (RD) is obtained following Stivers and Sun (2010), by simply calculating the daily cross-sectional standard deviation of 100 size and book-to-market sorted portfolios returns.

The US Business Cycle Expansion and Contraction indicator is provided by NBER. The reference dates and business cycle lengths are stated in the Internet Appendix C.

VI. Testing Model Predictions

In this section the theoretical insights provided in Section IV are investigated in an empirical setting, where the focus will lie on correlations, and the summary state variable of the model, which is PVGO. The difference in correlation among growth stocks and among value stocks, the predictive interplay of expected market-wide correlations and PVGO proxies, so as the

[12] From the perspective of the trade-off theory, growth firms should use less debt because growth opportunities are intangible assets, which cannot be used as collateral in the event of bankruptcy.

[13] Considering $MKTRF$, SMB, HML, MOM, RMW, and CMA.

[14] For the stock to be included in the beta computation for a given period t to $t + \Delta t$, it must have more than 30% of valid returns available.

[15] The SSR are either averaged equally; ($EWIV$) or market-cap-weighted ($VWIV$) across firms.

prediction of portfolios sorted on these PVGO proxies by expected market-wide correlations, can be seen as the major insights in this empirical analysis. In this section, new empirical observations, which are in line with the theory, are investigated and documented first. In a next step, new theoretical insights are getting connected to known empirically documented results (such as the market return predictability).

A. New Empirical Results in line with the Theory

A major hypothesis testable from the model is that the correlation between stocks (15) is an increasing function in the firms' PVGO, or in other words, that growth stocks comove more strongly among themselves compared to value stocks. First, the average correlation among growth and value stocks based on the B/M characteristic starting in 1965 is investigated.[16] For each yearly formation date t (June), all stocks in the corresponding decile are selected and the realized average correlation within the actual holding period from t to $t+1$ is calculated.[17] Figure 3, Panel A, displays the time-varying average correlation dynamics of the two portfolios and its difference (called Correlation Delta). As depicted in the plot, the Correlation Delta fluctuates around zero, with a time series average of around 2.5%. In Figure 3, Panel B, the Correlation Delta and the recession indicator are displayed together where peaks in the Correlation Delta are mostly associated with periods before a recession. Immediately recognizable, the largest Correlation Delta peak happened during the build up of the dot-com tech bubble where especially companies adapting new internet services experienced a huge market turmoil. In the 90s era such companies were the flagship growth stocks per se. Overall, the empirical evidence confirms that the comovement among growth and value stocks differs, and, depending on the economic conditions, they display different dynamics over time.

In the next part of this empirical analysis the theoretical insights from the model, concerning the correlation dynamics between two stocks, are tested and embedded in an aggregated market-

[16]A helpful Python code replicating the B/M sorted decile portfolios can be found on WRDS.

[17]For growth (value) stocks I consider stocks belonging to the lowest (highest) B/M sorted decile.

wide setting. Since time series predictions are formulated, the information content inherited in implied correlations, as a forward-looking measure for the market-wide correlation, is exploited.

[FIXME: LS# 3: Add lagged IC]

The second hypothesis states that, since the correlation between stocks is an increasing function of PVGO, implied correlation should predict changes in PVGO. The main results for the in-sample predictability of changes in the aggregate PVGO proxies by IC (controlling for its lagged values), can be inferred from Table VI, where the following predictive regressions is performed:

$$\Delta_{log} PVGO_{t \to t+\tau_r} = \gamma + \beta_{IC} IC(t, t+\tau_r) + \beta_{IC_{t-1}} IC(t-1, t+\tau_r) + \varepsilon_t, \tag{19}$$

thereby PVGO equals M/B, Q, DTE, or $CAPEX$. As displayed in Table VI, M/B, Q, and $CAPEX$ are positively related to IC with highly significant coefficients and with increasing R^2s for longer predictive horizons, while future changes in DTE are, as expected, negatively related to IC. As pointed out by Cao, Simin, and Zhao (2008), M/B, Q, and $CAPEX$ are positively related to the absolute average level of growth options, while DTE is negatively related.

PVGO is identified as the models central state variable for the explanation of the value premium, that is, the outperformance of value stocks over growth stocks (see (10)). Since changes in PVGO proxies are predicted by IC, it is expected that the predictive power of IC is inherited when predicting future returns on the value factor or B/M sorted portfolios. In order to illustrate the predictive relation of implied correlations and value factor returns, the following specification is performed:

$$r^F_{t \to t+\tau_r} = \gamma + \beta_{IC} IC(t, t+\tau_r) + \beta_{IC_{t-1}} IC(t-1, t+\tau_r) + \varepsilon_t, \tag{20}$$

where $r^F_{t \to t+\tau_r}$ denotes the factor return for a period from t to τ_r. In the regression I am controlling for the lagged values of IC (IC_{t-1}). Standard errors are corrected to account for autocorrelation introduced by overlapping return observations, see Newey and West (1987).[18]

[18] For non-overlapping observations is controlled in the Robustness Section IX.

The results for the in-sample return predictability are presented Table B2 Panel A and visually displayed in Figure 5 Panel A. IC predicts HML with a significant negative coefficient for all maturities, with increasing R^2s ranging from over 2% to almost 23% for a yearly return predictability. To better understand the source of prediction, the predictability of the long and short legs of the value factor returns (Table B2 Panel B and Figure 5 Panel B) are analyzed next. It turns out that IC does not predict value stocks (H) but rather the returns of growth stocks (L) with positive regression coefficient and, therefore, its difference HML (and HML^*) with a negative coefficient. In line, when predicting the 10 B/M portfolios, the significance and R^2s of the regression coefficients show a monotonic pattern, where the significance is increasing in portfolio deciles containing more and more growth stocks (see Table VIII and Figure 6). Overall, the return predictability draws a clear picture: Implied correlation predicts future value factor returns negatively. The predictiveness is primarily through the positive prediction of the short leg (L) and the low B/M portfolios, which are characterized through a higher amount of growth stocks.

To summarize, this section showed that the correlation dynamics among growth and value stocks differ and are time-varying. Expected market-wide correlation, as function of the PVGO, predicts not only changes in the PVGO, but also returns of portfolios sorted on one of the PVGO representatives (B/M).

B. Existing Empirical Results in Line with the Theory

In this section new theoretical insights are getting connected to known empirically documented results, such as the market return predictability by expected market-wide correlations. Two empirical results that have been documented in the past in the scope of market return prediction that support the theory that an average market-wide increase in $PVGO_M$ reduces the expected market return (11).

First, as reported by Cao, Simin, and Zhao (2008), the interplay of idiosyncratic variance, $PVGO_M$, and future market returns is in line with the new theoretical insights, since aggregate idiosyncratic volatility is (contemporaneously) positively related to $PVGO_M$. Guo and Savickas (2008) argue that the value-weighted idiosyncratic volatility measure is negatively related to the future equity premium (controlling for the market volatility).

Second, Pollet and Wilson (2010), Driessen, Maenhout, and Vilkov (2005), and Buss, Schoenleber, and Vilkov (2018) document that market-wide correlations (realized or implied) predict market returns positively for horizons up to one year. The contemporaneous (time series) correlation between IC (RC) and the proxies for PVGO are displayed in Table IV, and behave as expected: A high market correlation is associated with a low absolute level of growth options in the economy, and, therefore, the sign is negative (positive) for growth option proxies positively (negatively) related to growth options (M/B, Q, and $CAPEX$ vs. DTE).[19] The results are robust (but weaker) considering the differences in the growth options proxies (see Panel B). In line with the equation for expected market returns (11), low IC corresponds to a high level in $PVGO_M$ (contemporaneously), and, therefore, to a reduction of the future market return.

An additional way of connecting these two variables of interest is obtained when the contemporaneous time series correlation for the yearly IC (with 365 days maturity) and the (yearly) market-to-book value of the 10 decile portfolios is calculated. The time series correlation in Figure 4 displays a clear increasing monotonic pattern with the lowest (highest) value for the lowest (highest) B/M sorted portfolio (-0.5 vs. 0.2). Hence, the characteristics of low B/M portfolios (growth firms), are comoving negatively with an increase in IC, while the opposite is true, but less pronounced, for high B/M portfolios (value firms). As visible in Figure 8, the high market capitalization among low B/M stocks (growth stocks) contributes positively to this effect on a market level. As shown in the previous section, IC predicts the return on growth stocks (rather than the return on value stocks).

[19] Even though the contemporaneous relationship is on average negative, on a yearly rolling basis it displays time-varying patterns with high absolute correlations between -0.75 to 0.75.

Overall, the previously outlined connections motivate from a theoretical point of view the empirical finding that expected market-wide correlation (idiosyncratic volatility) positively (negatively) predicts future market returns.

VII. Correlation as a State Variable

As showed in the model section, the correlation between stocks inherits both, the firms systematic and the idiosyncratic growth dynamics, where the interplay of the two determine the shape and the level it. Not surprisingly, there are two main strands of literature connecting systematic and idiosyncratic risk to growth options, the market risk premium, the value premium, and finally to the business cycle. The empirical link between the various risk measures and (implied) correlations is investigated, and placed in the wider context. In Figure 10 an overview of the predictive (Panel A) and contemporaneous (Panel B) interplay between (implied) correlations, systematic and idiosyncratic risk, market- and value factor returns (and their respective long and short legs), and the PVGO is displayed. In both figures the blue-dashed dotted (red-dashed) line indicates a positive (negative) connection between two edges. Overall, correlation does not only predict the value factor and market returns by itself (as shown in the previous section) but also risk measures, which are known to be associated with the value premium, the market equity premium, and the PVGO. The sign of prediction is in line and consistent with prior literature and the new empirical observations.

In order to explore the existing risk channel predictive regressions for various risk measures on IC are performed,

$$Risk_{t \to t+\tau_r} = \gamma + \beta_{IC} IC(t, t+\tau_r) + \varepsilon_t, \tag{21}$$

where $Risk_{t \to t+\tau_r}$ denotes the realized risk measure for a period from t to τ_r. The set of risk measures consist of the dispersion of market betas $\sigma^2(\beta_M)$, value and growth betas (β_H, β_L), the cross-sectional return dispersion (RD), and the average idiosyncratic risk proxied by the equally and value-weighted sum of squared residuals ($EWIV$ and $VWIV$). The results are presented in Table XI.

Confirming the results of Buss, Schoenleber, and Vilkov (2018), IC predicts the dispersion of market betas for all horizons with a negative significant coefficient and R^2s ranging from 2% to 25%. An increase in market-wide correlation translates to a concentration of the market betas around their mean, decreasing the diversification possibilities. The results are in line with the findings of Santos and Veronesi (2004) that is, the dispersion of market betas is positively related to growth opportunities, which, in turn, are negatively related to the equity risk premium.

IC is loading negatively on the future average idiosyncratic risk, proxied by the equal ($EWIV$)–or value ($VWIV$)–weighted SSR. In line with the intuition, increasing correlation lowers the prevalent idiosyncratic risk in the market. Guo and Savickas (2008) finds that idiosyncratic volatility is negatively related to the future US equity premium (controlling for the market volatility), positively related to the future US value premium, and contemporaneously negative related to the aggregate B/M ratio. IC predicts future idiosyncratic stock market volatility, and is, therefore, indirectly related to the future US value premium.

For value and growth betas, the signs are in line with the results by Petkova and Zhang (2005), and IC positively (negatively) predict future value (growth) betas, and are, therefore, directionally correctly comoving with the expected market risk premium.

IC loads negatively on the future cross-sectional return dispersion (RD), indicating that the market moves intensified in one direction during times of turmoil. As Stivers and Sun (2010) argue: RD increases when the economy is slowing down, it is negatively related with the market return and positively related with the value premium.

Overall, the model theoretical insights, and the predictive relation of market-wide correlations to various risk measures, known to be associated with growth options, the value premium, and market returns, allows to draw the conclusion that IC serves as a leading procyclical state variable.

VIII. Additional Evidence

In this section I investigate whether implied correlations also predict other Fama and French (2015) value factors. In a next step the predictability is repeated, exploiting the more specific information content for implied correlations extracted for the S&P Value Index. At the end I conduct the return prediction out-of-sample.

A. Predicting Value Factors with Correlations Constructed for the S&P 500

Closely related to the book-to-market concept are factors considering the investment expenses or the individual operating profitability of the company. Such factors deliver an excess return by investing in companies with conservative versus aggressive investments expenses (CMA — Conservative Minus Aggressive) or by investing in companies with higher operating probability (RMW — Robust Minus Weak). The latter two portfolios can theoretically be linked to the B/M ratio of the company and, therefore, to the value premium; for a motivation, see Hou, Xue, and Zhang (2015), or Fama and French (2006).

In the first step of this additional investigation, the predictability and inheritable features of IC, w.r.t, other value strategies are analyzed. The main results can be summarized as follows: i) IC (extracted for the S&P 500) also predicts alternative value factor returns for horizons up to one year; ii) The predicting channel is evolving through the short legs of the considered value factors (A and W).

As shown in Table IX Panel A and visualized in Figure 7 (Panel A and Panel C), CMA (RMW) is also predicted negatively with an R^2 of about 20% (32%) for the yearly horizon. While CMA is always on the edge of being significant at the 5% level, RMW displays a strong significance across predictive horizons larger than one month. When investigating the predictability of the individual legs of the factors, see Table IX Panel B and Figure 7 (Panel B and Panel D), it turns out that IC positively predicts the short leg, that is, predicting returns on companies with aggressive investment behavior (A) and companies with low operating profitability (W), where the R^2s reach around 16% for the respective legs for a yearly horizon.

Since growth firms (low B/M ratio) tend to invest more, the results are in line with the economic theory around the linkage of operating profitability and investment expenditures to growth and value stocks provided by Fama and French (2006) and Zhang (2005). As discussed in Novy-Marx (2010), the profitability factor always merits some discussion. More profitable firms earn significantly higher average returns than unprofitable firms. They do so despite having, on average, lower B/M and higher market capitalization. Therefore, the profitability factor is considered a growth strategy rather than a value strategy. In terms of the author, IC predicts the returns on "bad value" firms (W).

B. *Predicting Value with Correlations Constructed for the S&P 500 Value Index*

In most studies, implied correlations are constructed for either broad major indices, such as the S&P 500, S&P 100, DJ 30, or the nine economic sectors of the S&P 500; see Driessen, Maenhout, and Vilkov (2005), Buss, Schoenleber, and Vilkov (2016), and Buss, Schoenleber, and Vilkov (2018). This paper is about value and growth, and, therefore, it seems natural to construct implied correlations for an value or growth equity index.

The S&P 500 Value Index (IVE) consists of value stocks, which are selected based on three characteristics: the ratios of book value, earnings, and sales to price. The index is rebalanced quarterly and its constituents are drawn from the S&P 500 parent index.[20] Index options are available starting from August 2006.[21] As shown in Table **??** Panel C, the mean of the expected correlation for the S&P 500 Value Index is on average larger and, in addition, more volatile, as

[20]S&P style indices divide the complete market capitalization of each parent index into growth and value segments.

[21]Implied correlations for the S&P 500 Growth Index are not constructed due to the late availability for the S&P 500 Growth Index Option data starting in 2012.

recognizable in Figure ??. The correlation between the regular IC and the IC_{IVE} ranges from 0.48 (for 30 days maturity) to 0.75 (for 365 days maturity).

In the following analysis, the information content of two different implied correlations, namely for the S&P 500 and the S&P 500 Value Index, will be compared in terms of predictability across the three value factors HML, CMA, and RMW.

As visible in Table ??, when running the in-sample predictive regressions starting from 2006, the value premia are predicted with a positive sign. The potential reason is that the correlation between market returns and HML is positive (0.33) starting from 2007, and, therefore, the value factor no longer displays a countercyclical behavior.

Figure ?? displays the in-sample R^2s for both predictors. Considering IC_{IVE} (instead of IC) increases the coefficient of determination by almost 33% (from 15% to 20%) at a yearly horizon when predicting HML. For CMA, both implied correlations predict similar. For the RMW growth factor, IC still outperforms IC_{IVE}.

The coefficient of determination is not the only way to ascertain whether there is a differential information content in IC_{IVE} over IC. Another approach is to decompose IC_{IVE} into its part explained by IC, and the additional information content represented by the residuals $\varepsilon_{IC_{IVE}}$,

$$IC_{IVE} = \alpha + \beta_{IC} IC + \varepsilon_{IC_{IVE}}. \tag{22}$$

In the next step, future factor returns ($MKTRF$, HML, CMA, and RMW) are regressed on (IC) and the residuals $\varepsilon_{IC_{IVE}}$

$$r^F_{t \to t+\tau_r} = \gamma + \beta_{IC} IC(t, t+\tau_r) + \beta_{\varepsilon_{IC_{IVE}}} \varepsilon_{IC_{IVE}} + \varepsilon_t, \tag{23}$$

where $r^F_{t \to t+\tau_r}$ denotes the factor return for a period from t to τ_r. The results of the described regression procedure are presented in Table ??. While the residuals ($Res_{IC_{IVE}} := \varepsilon_{IC_{IVE}}$) are not significant when predicting $MKTRF$, they indeed often matter when predicting value factor returns, indicating that the there is significant additional information content in IC_{IVE} over IC.[22]

C. Out-of-Sample Predictability

In this section the out-of-sample performance of the value factor returns for the two implied correlation measures IC and IC_{IVE} is compared and documented.

As in most studies, the forecasting performance of a specific model s is compared with the performance of a model based on the historical mean of the respective factor return ($s = 0$). Therefore the out-of-sample R^2 is calculated as

$$R^2_{s,\tau_r} = 1 - \frac{MSE_{s,\tau_r}}{MSE_{0,\tau_r}}, \tag{24}$$

where $MSE_{s,\tau_r} = \frac{1}{N}\sum^N e^2_{s,\tau_r}$ denotes the mean-squared error of model s computed from the prediction errors e_{s,τ_r} for horizon τ. A particular model, s, outperforms the benchmark model $s = 0$ based on the average historical return if the out-of-sample R^2_{s,τ_r} is significantly positive. Because of the limited availability of options data for the value index, the sample period only spans about 10 years. Consequently, asymptotic standard errors may not be accurate, so I resort to the moving-block bootstrap procedure of Künsch (1989).[23]

Out-of-sample predictions are based on rolling or expanding window estimations of the predictive in-sample regression (20) (with the addition of a time-specific intercept). The estimated coeffcient $\beta_{IC,t}$ together with the time-t value of IC_t then forms the out-of-sample return forecast $r^F_{t\to t+\tau_r}$. Note that, at date t, one uses only observations from the past to avoid any look-ahead bias.

Figure **??** and Figure **??** display the out-of-sample R^2 for univariate predictions using a rolling or expanding-window based on a five-year estimation period. The out-of-sample results

[22]Decomposing IC into IC_{IVE} and residuals (ε_{IC}), and then predicting $r^F_{t\to t+\tau_r} = \gamma + \beta_{IC_{IVE}} IC_{IVE}(t, t+\tau_r) + \beta_{\varepsilon_{IC}}\varepsilon_{IC} + \varepsilon_t$ leads to the same qualitative result. The beta coefficient for the residual ($\beta_{\varepsilon_{IC}}$) is not significance.

[23]Technically, I draw $10,000$ random samples (with replacement) of 200 blocks, with blocks of 12 observations (i.e., one-year blocks), to preserve the autocorrelation in the data. Using the bootstrapped distribution, the p-value for the null hypothesis: $R^2 = 0$ are computed.

are qualitatively similar to the in-sample results and not much affected by the selected estimation window (rolling vs. expanding). Important to notice, the predictability applying IC_{IVE} as predictor works as well as considering IC.

IX. Robustness

To verify the robustness results of the analysis to various specifications, a series of tests are carried out and reported in the Appendix B and the Internet Appendix C. In each subsection the robustness tests are roughly divided into the predictability of PVGO proxies and factor returns. Overall, the results in the main part of the paper are robust.

A. Non-Overlapping Predictions

Due to the autocorrelation introduced by overlapping changes in growth option proxies and factor returns, the variables of interest are sampled in a non-overlapping fashion. In Figure B1, the average R^2 for the growth option proxy predictability for each maturity is displayed. The non-overlapping sampling does not harm the R^2 when considering IC as an independent variable. The same procedure is applied to the factor returns' predictability and displayed in Figure B2. The monotonic increasing R^2's are not caused by overlapping return observations.

B. Predictions with Controls

In this subsection the in-sample predictions from Section VI are extended to control for (implied) market volatility (IV) and for a market-wide idiosyncratic risk proxy ($VWIV$); see Table B3 for growth option predictions and Table B4 for return predictions. For both types of predictions, IV does not show much of a significance. In line with the intuition, the idiosyncratic risk measure loads negatively on future growth options and positively on future value factor returns. Significance is rarely given and only at the 10% confidence.

In table B5 controls for the growth option proxies are incorporated when predicting future factor returns. For longer predictive horizons M/B predicts value factor returns positively. Together with IC, other growth options proxies (Q, DTE, and $CAPEX$) do not contribute significantly in predicting factor returns.

Table B6 presents the return predictability results when controlling for a larger set of common predictors. Specifically, the Earnings Price Ratio (EP), the Term Spread (TMS), the Default Yield Spread (DFY), the Book-to-Market Ratio (B/M), and the Net Equity Expansion (NTIS) are included in the regressions. These variables are constructed from the data following the procedures from the study of Goyal and Welch (2008).[24] EP is defined as the log ratio of earnings to prices; TMS is the difference between the long-term yield on government bonds and the Treasury bill; DFY is the difference between BAA- and AAA-rated corporate bond yields; B/M is the ratio of book value to market value for the Dow Jones Industrial Average, and NTIS is the ratio of 12-month moving sums of net issues by NYSE listed stocks divided by the total end-of-year market capitalization of NYSE stocks.

C. Full Sample, Expansion, and Contraction

In Table **??**, the predictive growth options regressions as stated in (19) are repeated for RC over the full sample (1983). RC predicts changes in future growth option proxies for a horizon up to a quarter.

In Table **??**, the return predictability is repeated starting from 1965, using RC as a predictor. The signs for the return predictions are consistent with the the usage of IC (Panel A). The value factor returns HML are predicted for horizons up to a quarter while returns on HML^* and growth stocks (L) (Panel B) are predicted for horizons up to one year.

The predictive growth options regressions are repeated over the respective subsample divided by the NBER recession indicator, Table **??**, for RC (starting in 1965) and Table **??** for IC (starting in 1996). For RC significance is not ensured even though the coefficients display

[24] I am grateful to the authors for providing the data on their website.

mostly the correct positive sign. Noticeably, the information content of IC stays comparable, regardless of the economic state of the world.

In the same fashion, the return predictability regressions are repeated over the respective subsample divided by the NBER recession indicator, Figure **??**, for RC (starting in 1965) and Figure **??** for IC (starting in 1996). The regressions considering RC reveal stronger predictive power in contraction states, especially for the market neutral value premium HML^*, with R^2s ranging from 2% to 24% and the five predictive horizons. The signs of the coefficients are consistently negative within the two subsamples, even though significance is sometimes missing. As displayed in Table **??**, Panel A and Panel B, within the contraction phases, IC predicts HML, the pure value premium (HML^*), and growth stocks (L). When considering expansion states, Panel C and Panel D, the results w.r.t IC are similar to the ones without the division into contraction and expansion.

D. PVGO across Industry Sectors

The exposure for the value of growth options proxies across different industry sectors is displayed in Figure B3. Not surprisingly the exposure for M/B, Q, and $CAPEX$ is the highest within the technology and health sector and the lowest in the utilities and materials sector. To summarize, the PVGO across different economic sectors do not show any extreme behavior or capture any industry effect.

X. Conclusion

This paper relates, theoretically and empirically, market-wide correlation and its dynamics to growth options, growth stocks, and the value premium. An increase in expected market-wide correlation happens due to an increase in expectations of economic growth. When firms accumulate growth options, growth stocks gain in value simultaneously, thus showing higher correlation. The higher valuation of growth stocks leads to decreasing returns on the value factor and increasing market returns.

New insights provided by the production model confirm that the correlation between firms is an increasing function of the firms PVGO. As it turns out, not only the return of value and growth stocks differ but also their correlation dynamics; that is, the correlation among growth stocks exceeds the correlation among value stocks. The correlation among growth and value portfolios is time-varying and its difference can be connected to the prevailing economic regime.

Empirically validated, the comovement among growth stocks is indeed stronger, compared to the comovement among value stocks, and expected market-wide correlations are able to predict future changes in growth options proxies with a positive sign. Since correlation predicts changes in the state variable which drives the value premium (PVGO), it is an immediate consequence that correlation significantly predicts future returns on the value factor for horizons up to one year with a negative sign. The predictiveness can be attributed to the ability of expected market-wide correlations predicting returns on stocks with low B/M ratios (growth stocks). Expected correlations extracted for the S&P 500 Value Index improve the predictability results in-sample and out-of-sample and further motivate the use of implied correlations beyond the large major indices.

The model relates the correlation between firms to the firms' systematic and idiosyncratic growth components. The insights, therefore, support existing and new empirical findings that relate market-wide correlations and idiosyncratic variances, via growth options, to aggregate market returns, the value premium, and the business cycle. Taking the results into consideration, it affirms the hypotheses that correlation serves as a leading procyclical state variable.

References

Angelidis, T., A. Sakkas, and N. Tessaromatis, 2015, "Stock market dispersion, the business cycle and expected factor returns," *Journal of Banking & Finance*, 59, 265–279.

Asness, C. S., J. A. Friedman, and J. M. Liew, 2000, "Style Timing: Values versus Growth," *The Journal of Portfolio Management*, 26(3).

Berk, J. B., R. C. Green, and V. Naik, 1999, "Optimal Investment, Growth Options and Security Returns," *The Journal of Finance*, LIV(5), 1553–1606.

Bollerslev, T., V. Todorov, and L. Xu, 2015, "Tail risk premia and return predictability," *Journal of Financial Economics*, 118(1), 113–134.

Buss, A., L. Schoenleber, and G. Vilkov, 2016, "Option-Implied Correlations, Factor Models, and Market Risk," .

——— , 2018, "Expected Correlation and Future Market Returns," Working Paper, FSFM.

Campbell, J. Y., M. Lettau, B. G. Malkiel, and Y. Xu, 2001, "Have Individual Stocks Become More Volatile? An Empirical Exploration of Idiosyncratic Risk," *The Journal of Finance*, 56(1), 1–43.

Cao, C., T. Simin, and J. Zhao, 2008, "Can Growth Options Explain the Trend in Idiosyncratic Risk?," *Review of Financial Studies*, 21(6).

Christoffersen, P., K. Jacobs, and B. Y. Chang, 2011, "Forecasting with Option Implied Information," CREATES Research Papers 2011-46, School of Economics and Management, University of Aarhus.

Dobelman, J., H. Kang, and S. Park, 2014, "WRDS Index Data Extraction Methodology," Technical Report TR-2014-01, Rice University, Department of Statistics.

Driessen, J., P. Maenhout, and G. Vilkov, 2005, "Option-Implied Correlations and the Price of Correlation Risk," Working paper, INSEAD.

——— , 2009, "The Price of Correlation Risk: Evidence from Equity Options," *Journal of Finance*, 64(3), 1375–1404.

Fama, E. F., and K. R. French, 1993, "Common Risk Factors in the Returns on Stock and Bonds," *Journal of Financial Economics*, 33(1), 3–56.

——— , 2006, "Profitability, investment and average returns," *Journal of Financial Economics*, 82, 491–518.

——— , 2008, "Dissecting Anomalies," *Journal of Finance*, 63(4), 1653–1678.

——— , 2015, "A five-factor asset pricing model," *Journal of Financial Economics*, 116(1), 1–22.

Garleanu, N., L. Kogan, and S. Panageas, 2012, "Displacement risk and asset returns," *Journal of Financial Economics*, 105, 491–510.

Gomes, J., L. Kogan, and L. Zhang, 2003, "Equilibrium Cross Section of Returns," *Journal of Political Economy*, 111(4), 693–732.

Goyal, A., and I. Welch, 2008, "A Comprehensive Look at The Empirical Performance of Equity Premium Prediction," *Review of Financial Studies*, 21(4), 1455–1508.

Gulen, H., Y. Xing, and L. Zhang, 2010, "Value versus Growth: Time-Varying Expected Stock Returns," NATIONAL BUREAU OF ECONOMIC RESEARCH.

Guo, H., and R. Savickas, 2008, "Average idiosyncratic volatility in G7 countries," *Review of Financial Studies*, 21(3), 1259–1296.

Hou, K., C. Xue, and L. Zhang, 2015, "Digesting Anomalies: An Investment Approach," *The Review of Financial Studies*, 28(3), 650–705.

Irvine, P. J., and J. Pontiff, 2009, "Idiosyncratic Return Volatility, Cash Flows, and Product Market Competition," *The Review of Financial Studies*, 22(3).

Kogan, L., and D. Papanikolaou, 2013, "Firm Chractersitics and Stock Returns: The Role of Investment-Specific Shocks," *The Review of Financial Studies*, (11), 2718–2759.

——— , 2014, "Growth Opportunities, Technology Shocks, and Asset Prices," *The Journal of Finance*, 69(2), 675–718.

Künsch, H. R., 1989, "The Jackknife and the Bootstrap for General Stationary Observations," *Ann. Statist.*, 17(3), 1217–1241.

Martin, I., 2013, "Simple Variance Swaps," NBER Working Paper 16884.

Newey, W. K., and K. D. West, 1987, "A Simple, Positive-semidefinite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix," *Econometrica*, 55(3), 703–708.

Novy-Marx, R., 2010, "The other Side of Value: Good Growth and the Gross Profitability Premium," NBER Working Paper Series.

Papanikolaou, D., 2011, "Investment Shocks and Asset Prices," *Journal of Political Economy*, 119(4), 639–685.

Petkova, R., and L. Zhang, 2005, "Is value riskier than growth?," *Journal of Financial Economics*, 78, 187–202.

Pollet, J. M., and M. Wilson, 2010, "Average correlation and stock market returns," *Journal of Financial Economics*, 96(3), 364–380.

Santos, T., and P. Veronesi, 2004, "Conditional Betas," University of Chicago and NBER.

Stivers, C., and L. Sun, 2010, "Cross-Sectional Return Dispersion and Time Variation in Value and Momentum Premiums," *The Journal of Financial and Quantitative Analysis*, 45(4), 987–1014.

Zhang, L., 2005, "The Value Premium," *The Journal of Finance*, LX(1).

Table I Summary Statistics – Correlation Measures

The table reports the summary statistics (time-series mean, p-value for the mean, median, standard deviation, the 10% and 90% percentile) for realized and implied correlations, which are calculated as equicorrelations, applying (17) for the S&P 500 Index, for five different maturities of 30, 91, 182, 273, and 365 calendar days. The sample period is ranging from 01/1996 to 12/2020. Second moments are calculated for the index and for all index components from daily realized returns over a respective window for realized variances and as model-free implied variances following Martin (2013) and are sampled on a daily frequency.

Panel A: Summary Statistics – RC

	$RC30$	$RC91$	$RC182$	$RC273$	$RC365$
Mean	0.321	0.323	0.326	0.323	0.323
p-val	0.000	0.000	0.000	0.000	0.000
Std	0.152	0.131	0.125	0.123	0.120
Per 10	0.150	0.171	0.179	0.178	0.175
Median	0.289	0.306	0.310	0.302	0.300
Per 90	0.534	0.489	0.475	0.515	0.518

Panel B: Summary Statistics – IC

	$IC30$	$IC91$	$IC182$	$IC273$	$IC365$
Mean	0.372	0.417	0.441	0.440	0.441
p-val	0.000	0.000	0.000	0.000	0.000
Std	0.125	0.109	0.100	0.096	0.091
Per 10	0.218	0.278	0.327	0.336	0.341
Median	0.360	0.414	0.444	0.439	0.440
Per 90	0.541	0.557	0.564	0.554	0.547

Table II Factor Return Correlation Overview

This table contains the time series correlation of the respective factor returns (sampled monthly), i.e, their long and short legs, and the B/M sorted portfolios as displayed in Panel A and in Panel B. The market neutral returns are estimated applying (18). The data is obtained from Kenneth French's website and ranges from 1996 to the end of 2020.

Panel A: Monthly Factor Return Correlation

	MKTRF	HML	H	L	HML*	IMC	I	C
MKTRF	1.000	-0.065	0.879	0.951	-0.034	0.617	0.906	0.897
HML	-0.065	1.000	0.351	-0.231	0.836	-0.215	-0.140	-0.024
H	0.879	0.351	1.000	0.829	0.304	0.530	0.784	0.779
L	0.951	-0.231	0.829	1.000	-0.188	0.677	0.895	0.821
HML*	-0.034	0.836	0.304	-0.188	1.000	-0.198	-0.116	-0.000
IMC	0.617	-0.215	0.530	0.677	-0.198	1.000	0.831	0.406
I	0.906	-0.140	0.784	0.895	-0.116	0.831	1.000	0.846
C	0.897	-0.024	0.779	0.821	-0.000	0.406	0.846	1.000

Panel B: Monthly B/M Portfolio Return Correlation

	MKTRF	HML	H	L	IMC	I	C
Lo10 BM	0.940	-0.288	0.715	0.914	0.601	0.870	0.852
Dec2 BM	0.952	-0.103	0.812	0.905	0.577	0.864	0.866
Dec3 BM	0.935	0.047	0.867	0.870	0.532	0.835	0.861
Dec4 BM	0.931	0.080	0.875	0.858	0.520	0.822	0.852
Dec5 BM	0.910	0.175	0.897	0.824	0.485	0.790	0.833
Dec6 BM	0.867	0.266	0.895	0.768	0.439	0.764	0.834
Dec7 BM	0.854	0.299	0.899	0.752	0.442	0.754	0.815
Dec8 BM	0.851	0.376	0.960	0.773	0.477	0.743	0.764
Dec9 BM	0.861	0.342	0.964	0.796	0.471	0.753	0.785
Hi10 BM	0.843	0.336	0.955	0.788	0.525	0.760	0.744

Table III PVGO Proxies

This table displays the summary statistics for the value of growth options. The proxies for PVGO include the ratio of the market value to book value of assets (M/B), an estimate of Tobin's Q (Q), the debt to equity ratio (DTE), and the ratio of capital expenditures to fixed assets ($CAPEX$). The data for the calculation of the PVGO proxies is obtained from Compustat and available on a monthly frequency from 1996 to the end of 2020. For further details, see Appendix A.

Panel A: Summary Statistics – PVGO Proxies

	$MABA$	Q	DTE	$CAPEX$
Mean	2.949	2.439	0.275	0.152
Std	1.578	1.605	0.116	0.049
Per 10	1.829	1.316	0.145	0.093
Median	2.576	2.057	0.254	0.151
Per 90	4.004	3.601	0.447	0.207
Skew	4.538	4.350	1.192	0.819

Table IV PVGO Proxies and Correlation Measures

This table displays the time series correlation of common proxies (and their changes) for the value of growth options with realized correlations (RC) calculated from daily realized returns over the respective window and implied correlations (IC) from matching-maturity options, both constructed for five different maturities of 30, 91, 182, 273, and 365 calendar days and for the S&P 500. The sample period for RC and for IC from 01/1996 to 12/2020. The proxies for PVGO include the ratio of the market value to book value of assets (M/B), an estimate of Tobin's Q (Q), the debt to equity ratio (DTE), and the ratio of capital expenditures to fixed assets ($CAPEX$). The data for the calculation of the PVGO proxies is obtained from Compustat and available on a monthly frequency from 1996 to the end of 2020. For further details see Appendix A.

Panel A: Contemporaneous Correlation – Levels on Levels

	$RC30$	$RC91$	$RC182$	$RC273$	$RC365$	$IC30$	$IC91$	$IC182$	$IC273$	$IC365$
M/B	-0.321	-0.386	-0.366	-0.354	-0.362	-0.414	-0.448	-0.494	-0.509	-0.515
Q	-0.319	-0.387	-0.368	-0.352	-0.360	-0.418	-0.447	-0.489	-0.503	-0.508
DTE	0.282	0.296	0.319	0.317	0.321	0.202	0.282	0.274	0.275	0.274
$CAPEX$	-0.230	-0.280	-0.319	-0.358	-0.375	-0.201	-0.276	-0.320	-0.338	-0.335

Panel B: Contemporaneous Correlation – Changes on Changes

	$RC30$	$RC91$	$RC182$	$RC273$	$RC365$	$IC30$	$IC91$	$IC182$	$IC273$	$IC365$
M/B	-0.032	-0.085	-0.084	-0.082	-0.084	-0.080	-0.110	-0.109	-0.077	-0.088
Q	-0.022	-0.086	-0.084	-0.077	-0.086	-0.105	-0.130	-0.119	-0.083	-0.092
DTE	0.136	0.051	0.086	0.083	0.100	-0.122	0.046	0.054	0.061	0.092
$CAPEX$	-0.015	-0.029	-0.058	-0.058	-0.039	0.045	-0.013	0.004	-0.006	-0.017

Table V IMC, PVGO Proxies and Correlation Measures

This table displays the time series correlation of common proxies (their changes) for the value of growth options, realized correlations (RC) calculated from daily realized returns over the respective window and implied correlations (IC) from matching-maturity options, both constructed for five different maturities of 30, 91, 182, 273, and 365 calendar days and for the S&P 500, with the IMC portfolio over the sample period from 01/1996 to 07/2020. The proxies for PVGO include the ratio of the market value to book value of assets (M/B), an estimate of Tobin's Q (Q), the debt to equity ratio (DTE), and the ratio of capital expenditures to fixed assets ($CAPEX$). The data for the calculation of the PVGO proxies is obtained from Compustat and available on a monthly frequency from 1996 to the end of 2020. For further details see Appendix A.

Panel A: Contemporaneous Correlation – Returns on Changes

	IMC
M/B	0.205
Q	0.193
DTE	-0.196
$CAPEX$	0.051

Panel B: Contemporaneous Correlation – Returns on Changes

	IMC
$RC30$	-0.288
$RC91$	-0.353
$RC182$	-0.382
$RC273$	-0.318
$RC365$	-0.377

Panel C: Contemporaneous Correlation – Returns on Changes

	IMC
$IC30$	-0.262
$IC91$	-0.321
$IC182$	-0.310
$IC273$	-0.319
$IC365$	-0.345

Table VI Predictive: PVGO Proxies – Changes

This table shows the slope and the R^2s of the univariate regressions of (log) changes of common proxies for the value of growth options over a future horizon of 30, 91, 182, 273, and 365 calendar days on implied correlations (IC) (and its lagged values) from matching-maturity options over the respective window. The sample period for RC and IC ranges from 01/1996 to 12/2020. The proxies for PVGO include the ratio of the market value to book value of assets (M/B), an estimate of Tobin's Q (Q), the debt to equity ratio (DTE), and the ratio of capital expenditures to fixed assets ($CAPEX$). The data for the calculation of the PVGO proxies is obtained from Compustat and available on a monthly frequency. For further details see Appendix A. The p-values are computed with Newey and West (1987) standard errors.

	30 days	91 days	182 days	273 days	365 days
M/B					
IC	0.034	0.257	0.817	1.030	1.046
	0.839	0.059	0.001	0.001	0.029
R^2	-0.259	8.976	14.587	15.631	19.372
Q					
IC	0.137	0.392	0.880	1.192	1.249
	0.490	0.029	0.009	0.000	0.018
R^2	-0.177	8.564	13.976	15.380	18.974
DTE					
IC	0.670	-0.130	-0.498	-0.674	-0.511
	0.027	0.291	0.017	0.014	0.044
R^2	0.727	5.526	8.784	7.210	7.091
$CAPEX$					
IC	-0.497	-0.522	0.011	0.635	0.486
	0.044	0.124	0.984	0.209	0.010
R^2	0.567	0.122	-0.679	0.192	8.429

Table VII Predictive: Factor Returns

The table shows the slope and the R^2s of the regressions of the excess market and value factor returns realized over a future horizon of 30, 91, 182, 273, and 365 calendar days on implied correlation (IC) (and its lagged values) for the S&P 500 Index, computed by applying (17) to model-free implied variances ($MFIV$) using out-of-the money options with the respective maturity. The sample period ranges from 01/1996 to 12/2020, sampled at monthly frequency. The market neutral returns are estimated applying (18) to the factor data, which is obtained from Kenneth French's website. The intercept is not shown. The p-values (under the slope) are computed with Newey and West (1987) standard errors.

Panel A: Factors

	Return, 30 days	Return, 91 days	Return, 182 days	Return, 273 days	Return, 365 days
MKTRF					
IC	-0.004	0.159	0.451	0.825	0.814
	0.928	0.012	0.000	0.000	0.000
R^2	4.440	16.079	22.541	23.047	21.822
HML					
IC	-0.042	-0.162	-0.351	-0.447	-0.582
	0.077	0.006	0.005	0.030	0.095
R^2	2.289	7.645	9.854	12.453	15.229
*HML**					
IC	-0.020	-0.141	-0.338	-0.409	-0.421
	0.376	0.014	0.004	0.016	0.066
R^2	2.062	6.945	8.435	9.601	10.687

Panel B: Legs

	Return, 30 days	Return, 91 days	Return, 182 days	Return, 273 days	Return, 365 days
H					
IC	-0.040	0.029	0.159	0.440	0.377
	0.483	0.733	0.238	0.039	0.200
R^2	1.359	3.281	3.784	3.234	2.346
L					
IC	-0.003	0.190	0.531	0.913	0.894
	0.946	0.019	0.000	0.000	0.001
R^2	3.889	14.335	21.233	21.073	19.455

Table VIII Predictive: B/M Sorted Portfolio Returns

The table shows the slope and the R^2s of the regressions of the Fama and French B/M sorted decile portfolio over a future horizon of 30, 91, 182, 273, and 365 calendar days on implied correlation (IC) (and its lagged values) for the S&P 500 Index, computed by applying (17) to model-free implied variances ($MFIV$) using out-of-the money options with the respective maturity. The sample period ranges from 01/1996 to 12/2020, sampled at monthly frequency. The factor data is obtained from Kenneth French's website. The intercept is not shown. The p-values (under the slope) are computed with Newey and West (1987) standard errors.

	Return, 30 days	Return, 91 days	Return, 182 days	Return, 273 days	Return, 365 days
Lo10 BM					
IC	0.019	0.221	0.616	0.998	1.029
	0.615	0.002	0.000	0.000	0.000
R^2	5.155	21.135	28.041	27.680	26.141
Dec2 BM					
IC	-0.007	0.149	0.435	0.755	0.722
	0.851	0.039	0.000	0.000	0.000
R^2	4.293	15.393	19.635	19.270	17.949
Dec3 BM					
IC	-0.001	0.157	0.329	0.705	0.596
	0.985	0.007	0.001	0.000	0.000
R^2	3.128	11.069	14.421	15.474	13.987
Dec4 BM					
IC	-0.020	0.128	0.337	0.674	0.567
	0.636	0.032	0.001	0.000	0.002
R^2	3.295	8.415	10.571	10.449	8.605
Dec5 BM					
IC	-0.011	0.105	0.249	0.550	0.480
	0.800	0.083	0.007	0.000	0.001
R^2	2.357	5.554	6.441	6.094	4.181
Dec6 BM					
IC	-0.025	0.085	0.234	0.541	0.453
	0.591	0.238	0.052	0.008	0.072
R^2	2.429	5.776	5.590	5.329	4.043
Dec7 BM					
IC	-0.009	0.094	0.243	0.578	0.509
	0.853	0.217	0.078	0.007	0.036
R^2	2.096	5.328	5.767	5.627	5.131
Dec8 BM					
IC	-0.036	0.020	0.106	0.416	0.304
	0.485	0.824	0.437	0.063	0.286
R^2	0.944	2.638	4.400	4.187	3.695
Dec9 BM					
IC	-0.043	0.034	0.170	0.410	0.367
	0.465	0.683	0.207	0.064	0.238
R^2	1.647	3.242	3.205	2.766	2.113
Hi10 BM					
IC	-0.055	-0.028	0.143	0.447	0.403
	0.426	0.792	0.360	0.040	0.179
R^2	0.876	2.900	2.725	1.792	0.911

Table IX Predictive: Factor Returns – CMA and RMW

The table shows the slope and the R^2s of the regressions of the value factor returns (CMA, CMA^*, RMW, and RMW^*) and their legs (C, A, R, and W) realized over a future horizon of 30, 91, 182, 273, and 365 calendar days on implied correlation (IC) for the S&P 500 Index, computed by applying (17) to model-free implied variances ($MFIV$) using out-of-the money options with the respective maturity. The sample period for IC ranges from 01/1996 to 12/2020, sampled at monthly frequency. The market-neutral returns are estimated applying (18) to the factor data, which is obtained from Kenneth French's website. The intercept is not shown. The p-values (under the slope) are computed with Newey and West (1987) standard errors.

Panel A: Factors

	Return, 30 days	Return, 91 days	Return, 182 days	Return, 273 days	Return, 365 days
CMA					
IC	-0.013	-0.064	-0.160	-0.238	-0.355
	0.307	0.055	0.024	0.061	0.107
R^2	0.058	4.431	10.475	16.691	20.235
*CMA**					
IC	-0.007	-0.022	-0.083	-0.088	-0.158
	0.490	0.478	0.089	0.317	0.283
R^2	-0.490	0.199	3.141	7.446	8.578
RMW					
IC	-0.007	-0.045	-0.121	-0.301	-0.378
	0.688	0.341	0.161	0.017	0.044
R^2	0.981	7.021	17.936	22.403	26.694
*RMW**					
IC	-0.000	0.009	0.004	-0.072	-0.085
	0.983	0.834	0.957	0.422	0.458
R^2	-0.605	1.424	5.719	7.195	9.061

Panel B: Legs

	Return, 30 days	Return, 91 days	Return, 182 days	Return, 273 days	Return, 365 days
C					
IC	-0.020	0.116	0.368	0.701	0.643
	0.664	0.121	0.001	0.000	0.008
R^2	3.395	9.318	11.347	9.869	8.110
A					
IC	-0.009	0.169	0.515	0.909	0.903
	0.856	0.043	0.000	0.000	0.001
R^2	3.457	13.221	20.021	20.344	18.573
R					
IC	-0.018	0.129	0.400	0.704	0.662
	0.697	0.050	0.000	0.000	0.004
R^2	3.292	10.050	11.992	10.878	8.709
W					
IC	-0.013	0.153	0.487	0.927	0.922
	0.807	0.098	0.000	0.000	0.001
R^2	3.529	12.760	19.677	19.568	18.597

Table X Risks and Correlation Measures

This table displays the time series correlation of common proxies (their changes) for risks associated to the value of growth options, with realized correlations (RC) calculated from daily realized returns over the respective window and implied correlations (IC) from matching-maturity options, constructed for 30 calendar days and for the S&P 500 over the sample period from 01/1996 to 07/2020. Obtained from the CAPM for the whole CRSP universe, the $\sigma^2(\beta_M)$ denotes the cross-sectional dispersion of market betas, $EWIV$ ($VWIV$) the equally (value) weighted sum of squared residuals. β_H (β_L) value (growth) betas are calculated by regressing excess returns of value (growth) portfolios on market excess returns. The measures are constructed over a 60 months rolling window using monthly return data. Return Dispersion (RD) is calculated as the cross-sectional dispersion of the 100 size and B/M sorted monthly portfolios returns. RV denotes the realized variance of the SP 500 index.

Panel A: Contemporaneous Correlation – Levels on Levels

	RV	$\sigma^2(\beta_M)$	β_H	β_L	$VWIV$	$EWIV$	RD
$RC30$	0.509	-0.315	0.253	-0.208	-0.105	-0.132	-0.093
$IC30$	0.348	-0.283	0.267	-0.310	-0.079	-0.084	-0.172

Panel B: Contemporaneous Correlation – Changes on Changes

	RV	$\sigma^2(\beta_M)$	β_H	β_L	$VWIV$	$EWIV$	RD
$RC30$	0.372	-0.014	-0.002	-0.053	-0.146	-0.056	-0.077
$IC30$	0.181	-0.044	-0.059	-0.018	-0.198	-0.078	0.008

Table XI Predictive: Risks – Market Level

This table reports the regression coefficients (with corresponding p-values) and the R^2s from regressions of various risk measures on implied correlations (IC) for horizons of 30, 91, 182, 273, and 365 calendar days, calculated by applying (17) for the S&P 500 Index over the sample period ranging from 01/1996 to 12/2020. Obtained from the CAPM for the whole CRSP universe, the $\sigma^2(\beta_M)$ denotes the cross-sectional dispersion of market betas, $EWIV$ ($VWIV$) the equally (value) weighted sum of squared residuals. β_H (β_L) value (growth) betas are calculated by regressing excess returns of value (growth) portfolios on market excess returns. The measures are constructed over a 60 months rolling window using monthly return data. Return Dispersion (RD) is calculated as the cross-sectional dispersion of the 100 size and B/M sorted monthly portfolios returns. RV denotes the realized variance of the SP 500 index. The intercept is not shown. The p-values are computed with Newey and West (1987) standard errors.

	30 days			91 days			182 days			273 days			365 days		
	β	$p-val$	R^2	β	$p-val$	R^2	β	$p-val$	R^2	β	$p-val$	R^2	β	$p-val$	R^2
RV															
IC	0.281	0.014	9.808	0.173	0.025	2.558	0.050	0.381	0.258	0.001	0.991	0.466	0.003	0.942	0.476
$\sigma^2(\beta_M)$															
IC	-1.911	0.184	1.260	-3.653	0.097	2.037	-1.827	0.529	0.569	1.437	0.571	2.388	-5.408	0.087	1.556
β_H															
IC	0.246	0.055	8.715	0.382	0.027	14.356	0.598	0.002	27.120	0.727	0.001	36.798	0.792	0.002	36.337
β_L															
IC	-0.098	0.011	10.966	-0.126	0.006	18.319	-0.184	0.001	30.881	-0.197	0.002	37.791	-0.223	0.001	39.576
$VWIV$															
IC	-0.090	0.363	-0.181	-0.228	0.106	3.039	-0.365	0.078	8.095	-0.417	0.098	12.886	-0.458	0.076	12.877
$EWIV$															
IC	-0.175	0.440	-0.080	-0.405	0.159	2.792	-0.710	0.044	10.701	-0.887	0.028	19.239	-1.075	0.018	21.371
RD															
IC	-0.034	0.186	3.289	-0.076	0.056	14.311	-0.170	0.001	26.290	-0.220	0.001	29.721	-0.224	0.003	20.980

Figure 1. Realized and Implied Correlations

The figure shows the time series plot (i.e., the 21 days moving average) of realized correlation (RC) and implied correlation (IC) for a maturity of 30 and 365 calender days, in Panel A and Panel C. In Panel B and Panel D, RC and IC with a maturity of 30 days are displayed together with the NBER Recession Indicator (see Appendix C4), which equals 1 if the economy is in recession and 0 elsewhere (expansion). RC and IC are calculated as equicorrelations applying)17) for the S&P 500 Index for five different maturities of 30, and 365 calendar days. The sample period for RC is ranges from 01/1965 to 12/2017 and for IC extracted for the S&P 500 from 01/1996 to 12/2017. Second moments are calculated for the index and for all index components from daily realized returns over a respective window for realized variances and as model-free implied variances following Martin (2013) and are sampled on a daily frequency. In the plots the 30 days moving average is depicted.

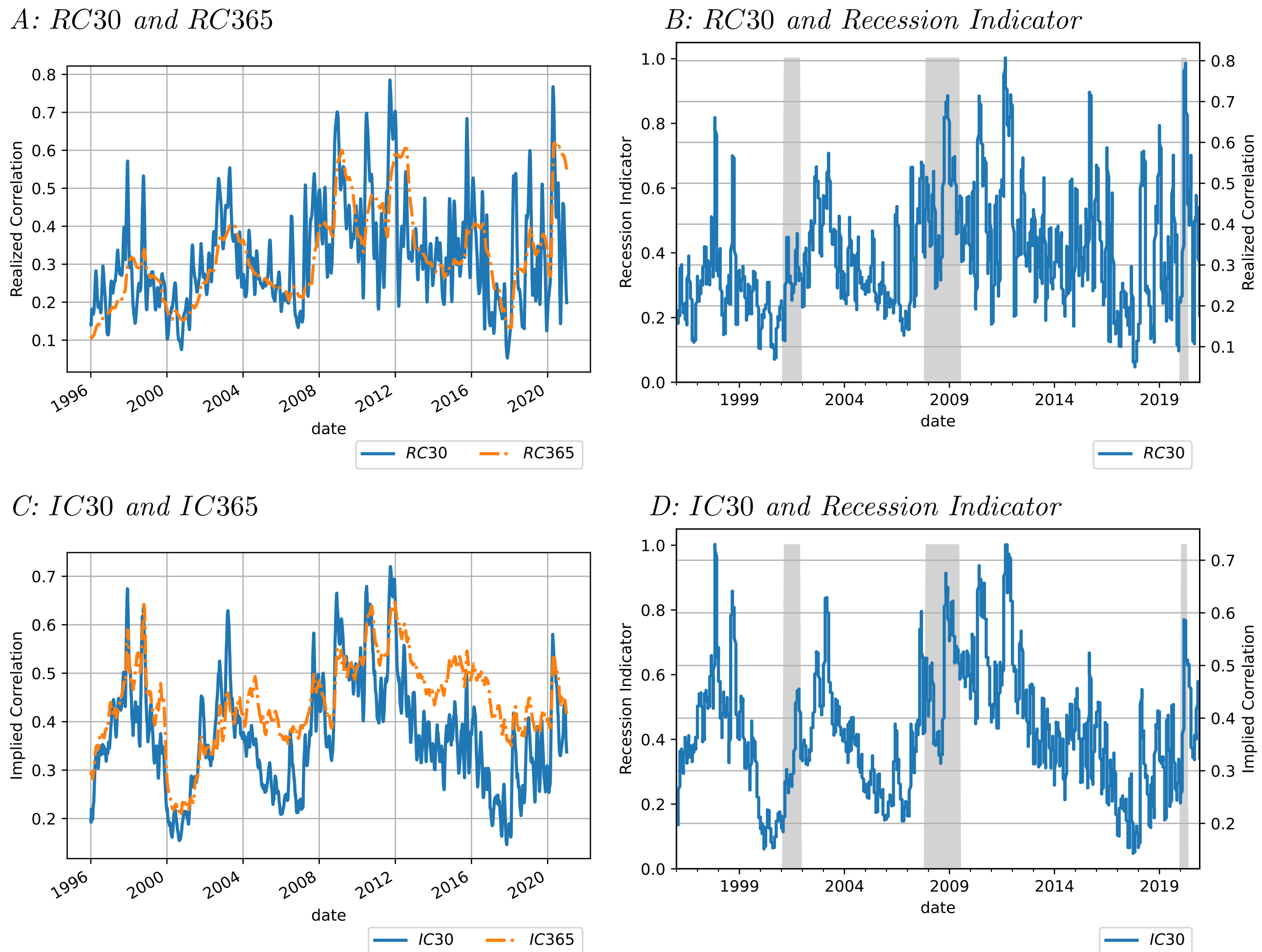


Figure 2. Correlations and IST Shocks

The figure displays the average dynamics of realized correlations (RC) calculated from daily realized returns over the respective window and implied correlations (IC) from matching-maturity options, both constructed for a maturity of 30 calendar days and for the S&P 500 and IST shocks, proxied by the 25% largest absolute realizations of the IMC portfolio. The sample period for RC, IC, and IMC ranges from 01/1996 to 12/2020. All variables are sampled at a monthly frequency. Plots are normalized so that the IST shocks happens between -1 and 0. In the plots the 3 months moving average is depicted.

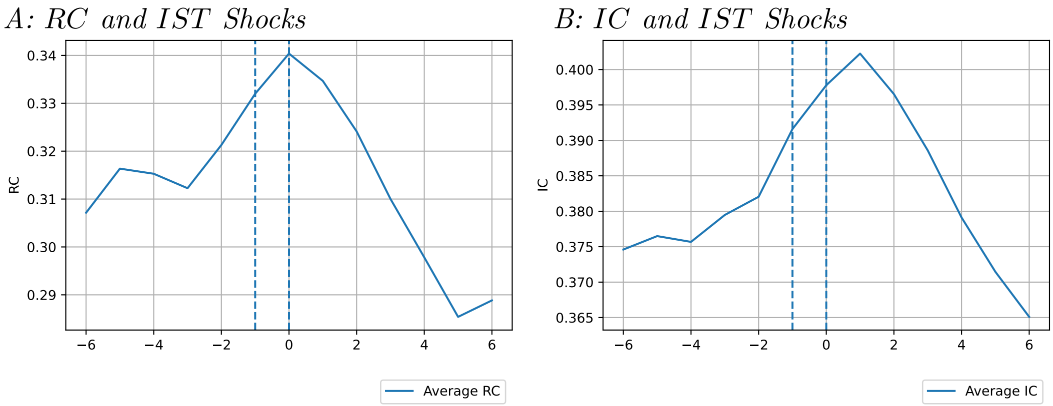


Figure 3. Average Correlation in B/M Sorted Portfolios

The figure shows the time series plots of the difference in the average correlation in growth portfolios (ρ(Lo10 BM)) and the average correlation in value portfolios (ρ(Hi10 BM)), called Correlation Delta (ρ(Lo10 BM) $-$ ρ(Hi10 BM)). The yearly average correlation among the various portfolios is calculated in forward-looking manner from t to $t+1$, where t denotes the rebalancing month (June). The sample period for the measures ranges from 01/1965 to 06/2020. In Panel A the Correlation Delta is displayed together with the NBER Recession Indicator (see Appendix **??**), which equals 1 if the economy is in recession and 0 elsewhere (expansion).

A: Correlation Delta and Recession Indicator

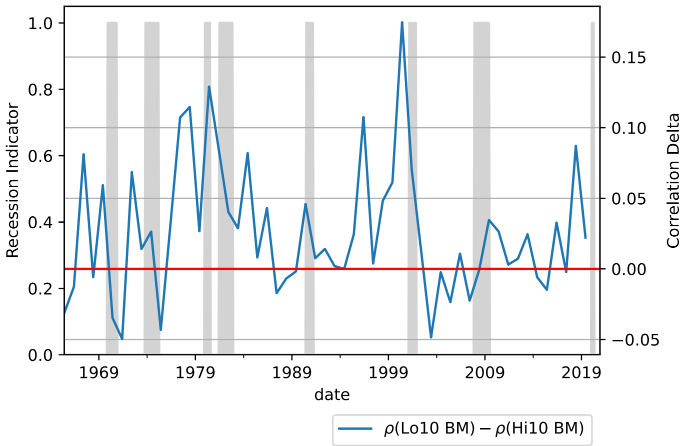


Figure 4. Contemporaneous: Correlations and M/B Characteristics

The figure shows the time series correlation of realized correlation (RC) and implied correlation (IC) for a maturity of 365 calendar days and the value-weighted market-to-book values of the 10 book-to-market sorted portfolios. The market-to-book characteristics for year t are available at Kenneth French's website. Therefore, the book value of year t is the book equity for the last fiscal year end in $t-1$, and the market value is price times shares outstanding at the end of December of $t-1$. Since B/M is calculated in December of $t-1$, RC and IC are sampled at the end of December in $t-1$ (Panel A and Panel B). The sample period for RC and for IC extracted for the S&P 500 from 01/1996 to 12/2020. The dashed line displays the time series correlation w.r.t. the average value-weighted M/B characteristic across all deciles.

A: Correlation – $RC_{Dec,t-1}$ *B: Correlation – $IC_{Dec,t-1}$*

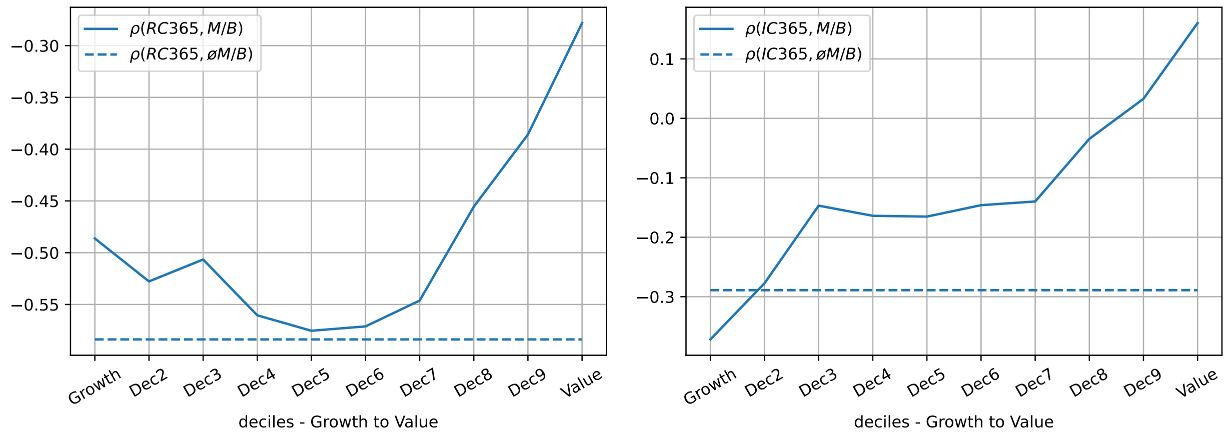


Figure 5. Predictive: Factor Returns

The figure shows the R^2s of the regressions of the value factor returns (HML, HML^*) and the individual long and short legs returns of the factors (H, L), realized over a future horizon of 30, 91, 182, 273, and 365 calendar days on implied correlations (IC) (and its lagged values) for the S&P 500 Index from matching-maturity options. The sample period is from 01/1996 to 12/2020, and the variables are sampled at monthly frequency. The market neutral returns are estimated applying (18) to the factor data, which is obtained from Kenneth French's website.

A: R^2 – Factors *B: R^2 – Legs of the Factors*

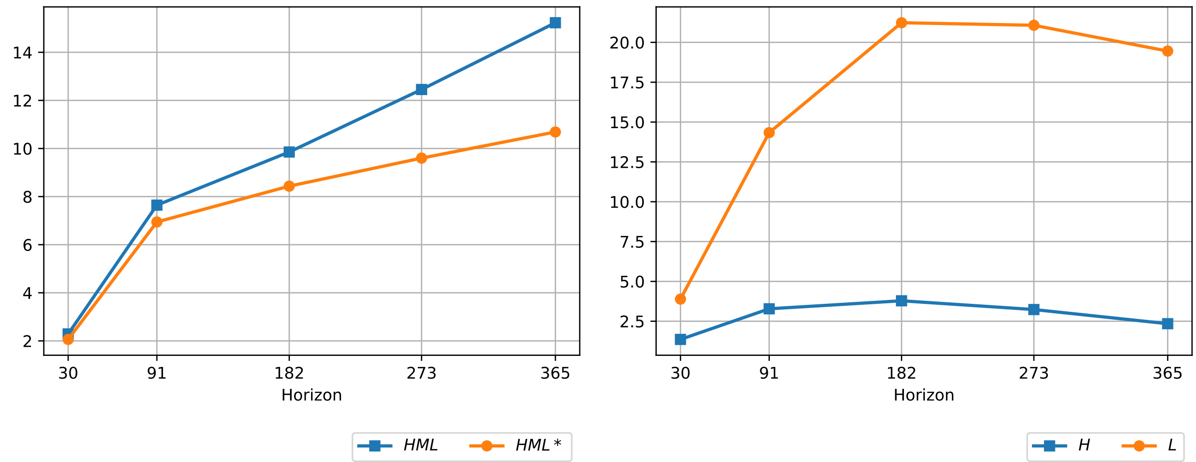


Figure 6. Predictive: B/M Sorted Decile Portfolios

The figure shows the R^2s (Panel A) and the p-values (Panel B) of the regressions of the Fama and French B/M sorted decile portfolios, realized over a future horizon of 30, 91, 182, 273, and 365 calendar days on implied correlations (IC) (and its lagged values) for the S&P 500 Index from matching-maturity options. The sample period is from 01/1996 to 12/2020, and the variables are sampled at monthly frequency. The factor data is obtained from Kenneth French's website.

A: R^2 – Factors *B: p-values*

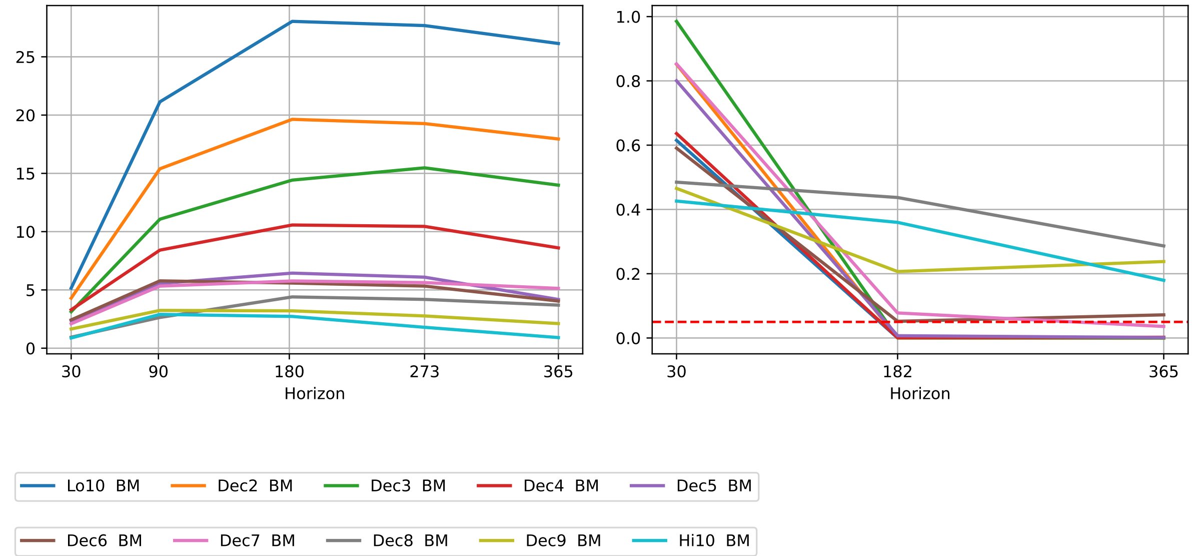
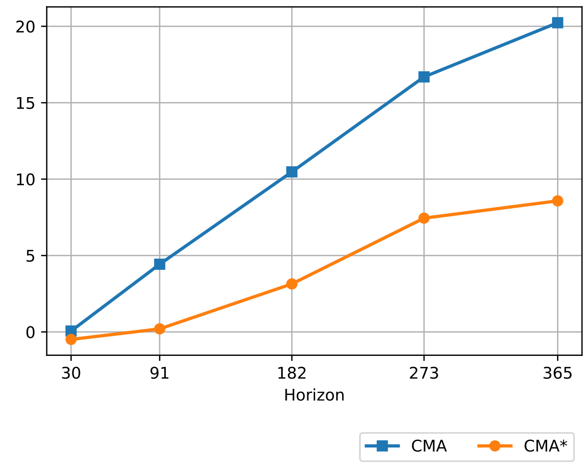


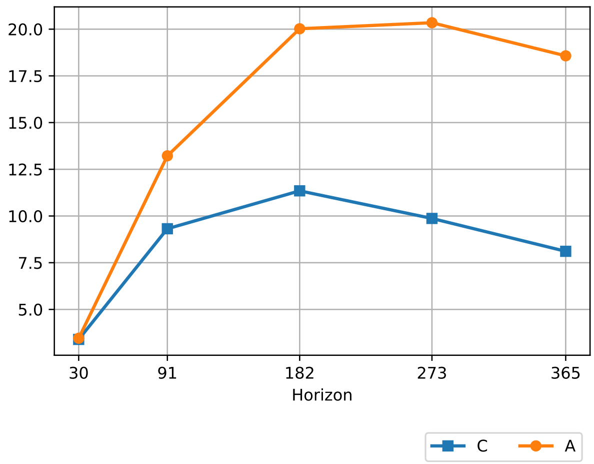
Figure 7. Predictive: Factor Returns – CMA and RMW

The figure shows the R^2s of the regressions of the value factor returns (CMA, CMA^*, RMW, RMW^*) and the individual long- and short legs returns of the factors (C, M, R, W), realized over a future horizon of 30, 91, 182, 273, and 365 calendar days on implied correlations (IC) (and its lagged values) for the S&P 500 Index from matching-maturity options. The sample period is from 01/1996 to 12/20202, and the variables are sampled monthly. The market-neutral returns are estimated applying (18) to the factor data, which is obtained from Kenneth French's website.

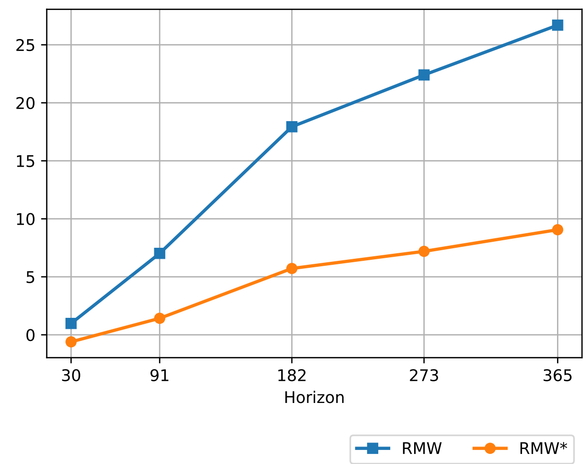
A: R^2 – Factors



B: R^2 – Legs of the Factors



C: R^2 – Factors



D: R^2 – Legs of the Factors

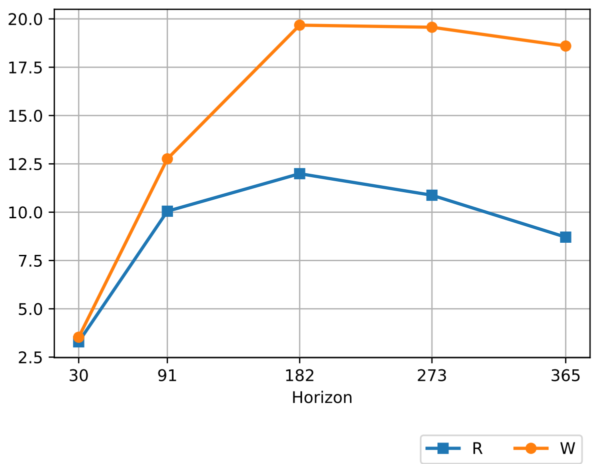


Figure 8. Market Capitalization of B/M Sorted Decile Portfolios

The figure shows the relative market capitalization of 10 B/M sorted portfolios, calculated as number of firms multiplied by the average firm size, in the respective deciles. The sample period ranges from 01/1926 to 12/2017 and is available on a monthly frequency. The factor data is obtained from Kenneth French's website. In the plots, the 12 month moving average is depicted.

A: Market Capitalization – B/M Sorted Deciles

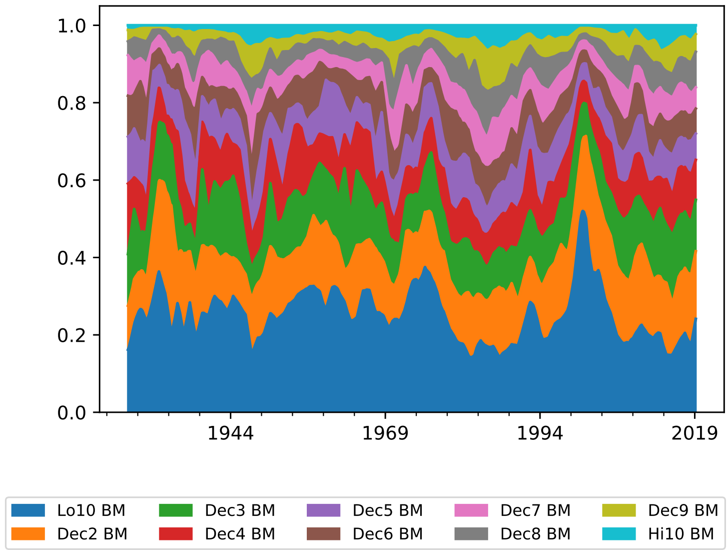
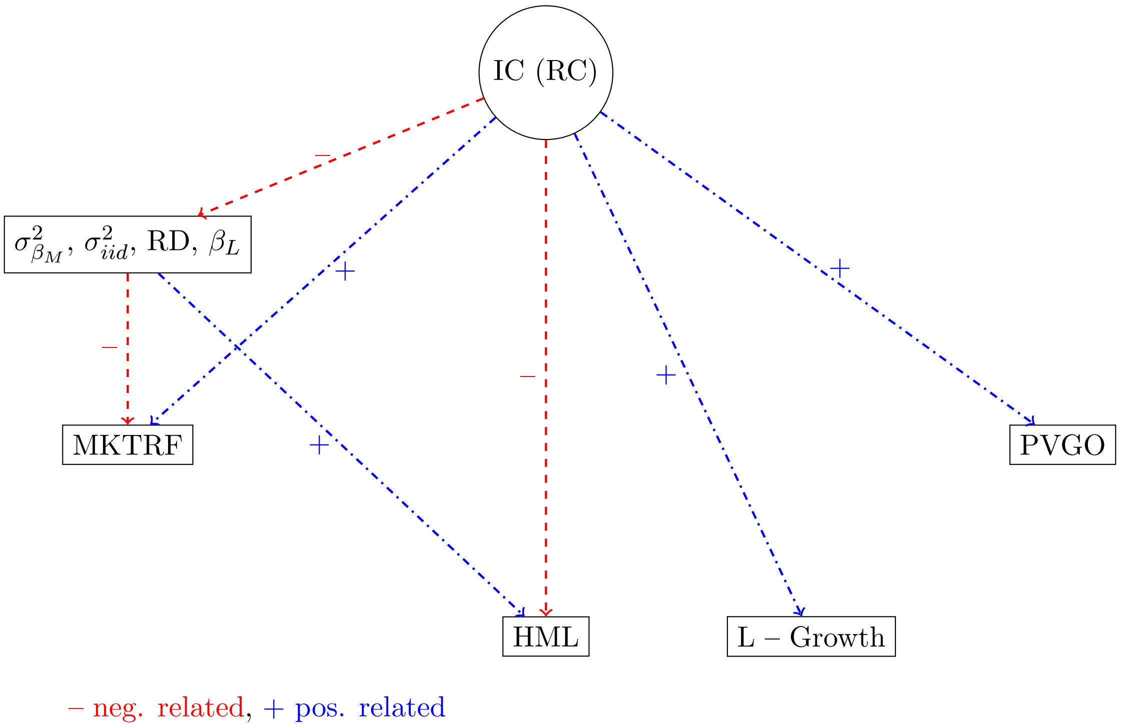


Figure 9. Correlation as a State Variable – Interplay with Risks, *PVGO*, and Returns

The figure displays the relation between *IC* (at time *t*) and future risk variables, the *PVGO*, and factor returns (Panel A). In Panel B the contemporaneous relation between implied correlations, risk variables, the present value of growth options, and factor returns is depicted. The network is collected from several empirical and theoretical research papers explained in Section III and complemented by the findings in this paper.

A: The Predictive Interplay of Market-Wide Correlations, Risks, Growth Options, and Returns



B: The Contemporaneous Interplay of IC, Risks, Growth Options, and Returns

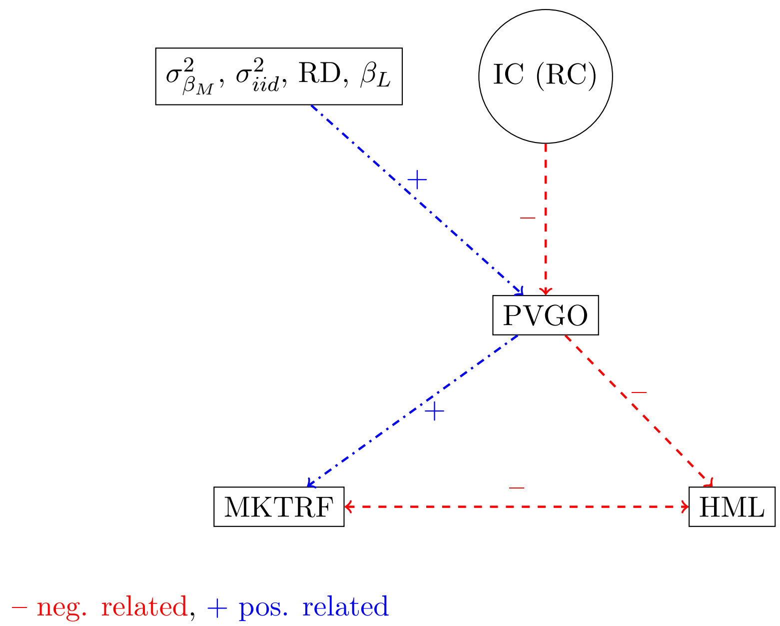
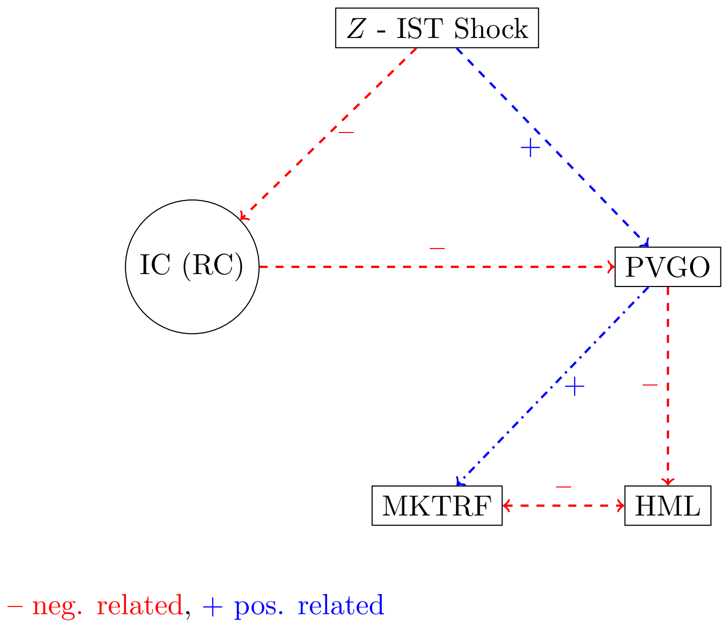


Figure 10. Correlation as a State Variable – Interplay with IST, $PVGO$, and Returns

The figure displays the relation between IC (at time t) and future risk variables, the $PVGO$, and factor returns (Panel A). In Panel B the contemporaneous relation between implied correlations, risk variables, the present value of growth options, and factor returns is depicted. The network is collected from several empirical and theoretical research papers explained in Section III and complemented by the findings in this paper.

A: The Contemporaneous Interplay of IC, Risks, Growth Options, and Returns



B: The Predictive Interplay of Market-Wide Correlations, Risks, Growth Options, and Returns

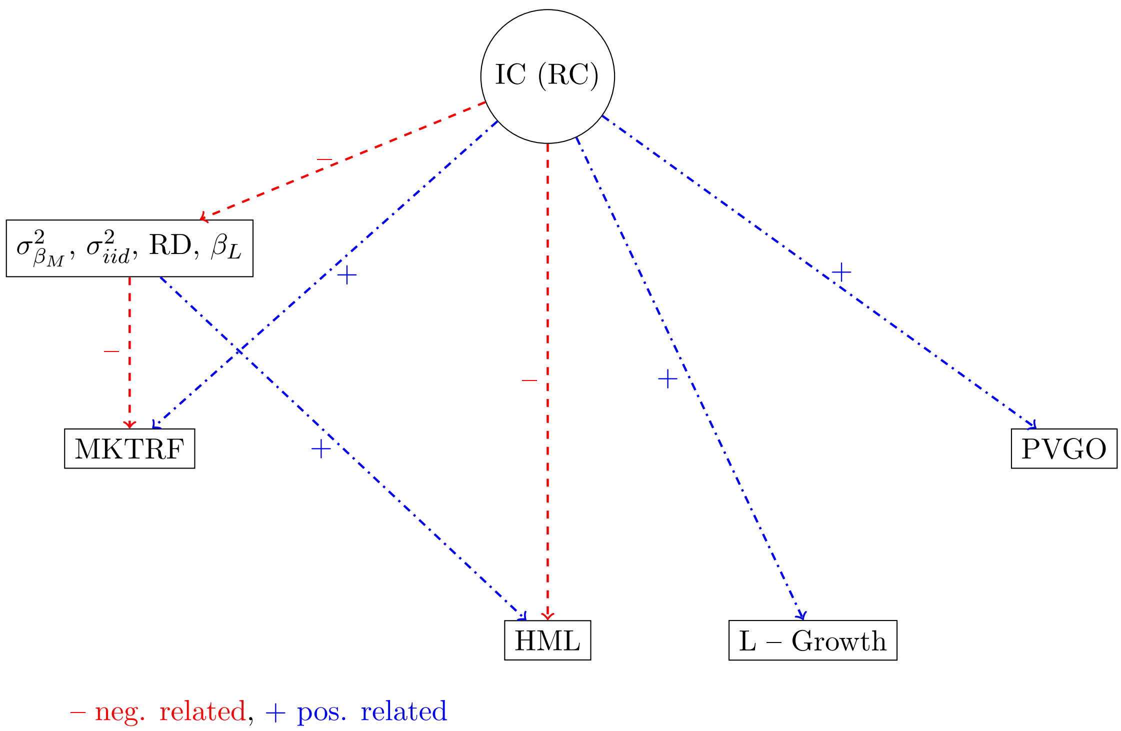


Figure 11. Market-Wide Correlations in the Model

The figure displays the correlation between two stocks as calculated in equation (15) for different idiosyncratic levels. Therefore, $\sigma_x = 0.17$, $\alpha = 0.85$, $\sigma_z = 0.035$, and $V_k = V_l = 1$ normalized to one. The function is evaluated for $PVGO_k$ and $PVGO_l$ between 0 and 1.

A: Correlation - Idiosyncratic = 0.1 *B: Stock Correlation - Idiosyncratic = 0.2*

zFigs/MFdgs/Model_Idiorr0_Idipdf_2.pdf

C: Stock Correlation - Idiosyncratic = 0.3 *D: Stock Correlation - Idiosyncratic = 0.4*

zFigs/MFdgs/Model_Idiorr0_I3ipdf_4.pdf

Appendix

Appendix A. Proxies for PVGO

I follow Cao, Simin, and Zhao (2008) to calculate the proxies for the growth options: The ratio of the market value to book value of assets (M/B), an estimate of Tobin's Q (Q), the debt to equity ratio (DTE), and the ratio of capital expenditures to fixed assets ($CAPEX$).

$$M/B = (ATQ - CEQQ + PRCCQ \times CSHOQ)/ATQ \tag{A1}$$

$$Q = (PRCCQ \times CSHOQ + PSTKQ + LCTQ - ACTQ + DLTTQ)/ATQ \tag{A2}$$

$$DTE = (DLCQ + DLTTQ + PSTKQ)/(PRCCQ \times CSHOQ) \tag{A3}$$

$$CAPEX = CAPXY/PPENTQ \tag{A4}$$

Table A1 Compustat Items - Calculation of Growth Option Proxies

Item #	Name	Description
5	$LCTQ$	Current Liabilities - Total
6	ATQ	Assets - Total
14	$PRCCQ$	Price
19	$DVPQ$	Dividends - Preferred
40	$ACTQ$	Current Assets - Total
42	$PPENTQ$	Property Plant and Equipment - Total (Net)
44	ATQ	Assets-Total
45	$DLCQ$	Debt in Current Liabilities
49	$LCTQ$	Current Liabilities - Total
51	$DLTTQ$	Long-Term Debt - Total
55	$PSTKQ$	Preferred/Preference Stock (Capital) - Total
59	$CEQQ$	Common/Ordinary Equity - Total
61	$CSHOQ$	Common Shares Outstanding
90	$CAPXY$	Capital Expenditures
308	$OANCFY$	Operating Cash Flow

To reduce outliers when calculating the dept to equity ratio I exclude stocks with market capitalization below 1 million US$ and financials (sic code between 6000 and 6999). I include only common stocks (CRSP share code in 10 or 11).

Appendix B. Robustness

Figure B1. Predictive: PVGO Proxies – Changes – Non-overlapping

This figure reports the average R^2s and the t-statistics of the univariate predictive regressions of future (log) changes of common proxies for the present value of growth options (PVGO) over a future horizon of 30, 91, 182, 273, and 365 calendar days on implied correlations (IC) (and its lagged values) from matching-maturity options calculated for the S&P 500. The sample period ranges from 01/1996 to 12/2020. The data is sampled on a frequency equal to the predictive horizon (i.e., non-overlapping). The proxies for PVGO include the ratio of the market value to book value of assets (M/B), an estimate of Tobin's Q (Q), the debt to equity ratio (DTE), and the ratio of capital expenditures to fixed assets ($CAPEX$). The data for the calculation of the proxies is obtained from Compustat and available on a monthly frequency. For further details, see Appendix A.

A: R^2 – GO Proxies *B: t-stats – GO Proxies*

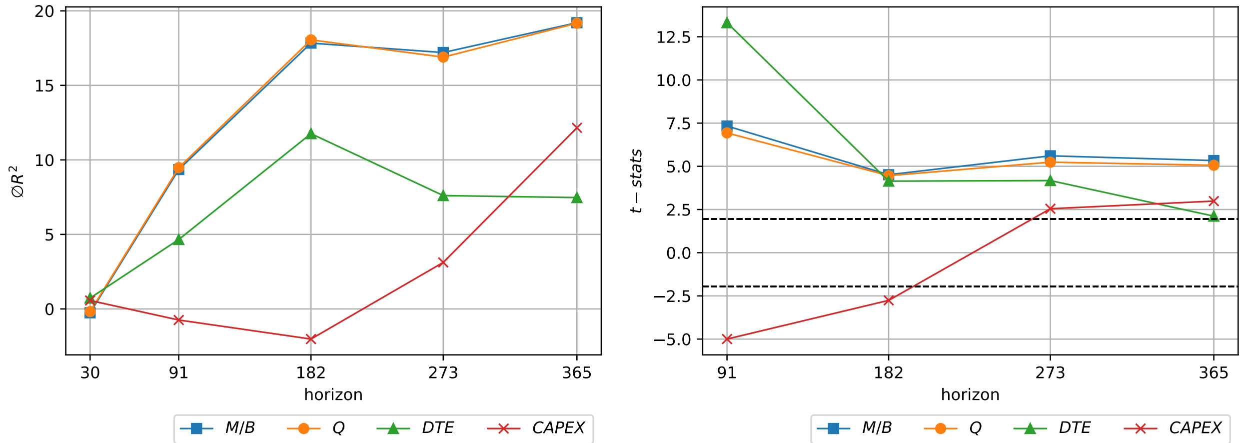


Figure B2. Predictive: Factor Returns – Non-overlapping

The figure shows the average R^2s of the regressions of the value factor returns (HML, HML^*, CMA, CMA^*, RMW, and RMW^*), realized over a future horizon of 30, 91, 182, 273, and 365 calendar days on implied correlations (IC) (and its lagged values) for the S&P 500 Index from matching-maturity options. The sample period ranges from 01/1996 to 12/2020. The data is sampled at a frequency equal to the predictive horizon (i.e., non-overlapping). The market-neutral returns are estimated applying (18) to the factor data, which is obtained from Kenneth French's website.

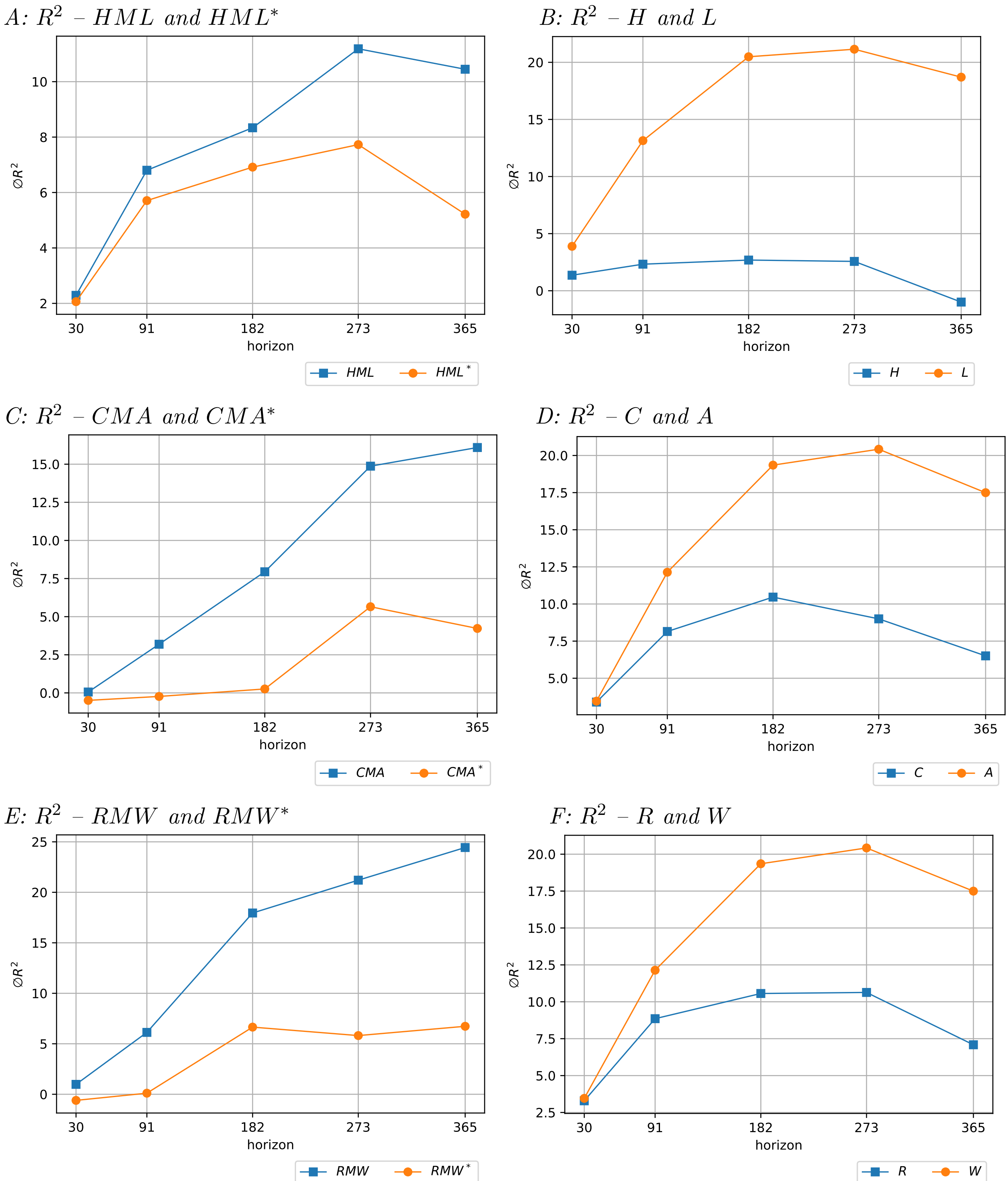


Table B1 Predictive: PVGO Proxies – Changes

This table shows the slope and the R^2s of the univariate regressions of (log) changes of common proxies for the value of growth options over a future horizon of 30, 91, 182, 273, and 365 calendar days on realized correlations (RC) (and its lagged values) from calculated from daily realized returns over the respective window. The sample period ranges from 01/1996 to 12/2020. The proxies for PVGO include the ratio of the market value to book value of assets (M/B), an estimate of Tobin's Q (Q), the debt to equity ratio (DTE), and the ratio of capital expenditures to fixed assets ($CAPEX$). The data for the calculation of the PVGO proxies is obtained from Compustat and available on a monthly frequency. For further details see Appendix A. The p-values are computed with Newey and West (1987) standard errors.

	30 days	91 days	182 days	273 days	365 days
M/B					
RC	-0.038	0.340	0.918	0.464	0.558
	0.726	0.039	0.005	0.304	0.392
R^2	-0.547	5.052	3.450	1.283	2.920
Q					
RC	-0.052	0.360	1.068	0.657	0.653
	0.687	0.059	0.003	0.200	0.392
R^2	-0.591	4.543	3.544	1.184	2.662
DTE					
RC	0.205	-0.094	-0.648	0.055	0.493
	0.303	0.550	0.075	0.882	0.441
R^2	0.573	3.441	3.553	0.208	2.185
$CAPEX$					
RC	-0.217	0.257	0.127	0.063	-1.728
	0.133	0.428	0.848	0.928	0.019
R^2	0.598	-0.505	-0.604	-0.691	3.030

Table B2 Predictive: Factor Returns

The table shows the slope and the $R^2 s$ of the regressions of the excess market and value factor returns realized over a future horizon of 30, 91, 182, 273, and 365 calendar days on realized correlation (RC) (and its lagged values) for the S&P 500 Index. Realized correlation are obtained via Eq. (17) and calculated from daily realized returns over a respective backward-looking window, corresponding to the predictive horizon. The sample period ranges from 01/1996 to 12/2020, sampled at monthly frequency. The market neutral returns are estimated applying (18) to the factor data, which is obtained from Kenneth French's website. The intercept is not shown. The p-values (under the slope) are computed with Newey and West (1987) standard errors.

Panel A: Factors

	Return, 30 days	Return, 91 days	Return, 182 days	Return, 273 days	Return, 365 days
MKTRF					
RC	0.008	0.120	0.285	0.645	0.717
	0.740	0.224	0.142	0.066	0.194
R^2	1.637	6.855	8.564	10.035	12.208
HML					
RC	-0.022	-0.194	-0.480	-0.315	-0.136
	0.118	0.002	0.001	0.121	0.681
R^2	1.939	5.958	4.122	0.547	1.566
*HML**					
RC	-0.010	-0.177	-0.504	-0.419	-0.210
	0.505	0.012	0.001	0.052	0.442
R^2	2.455	7.670	7.013	3.233	5.387

Panel B: Legs

	Return, 30 days	Return, 91 days	Return, 182 days	Return, 273 days	Return, 365 days
H					
RC	-0.014	-0.002	-0.160	0.531	0.985
	0.656	0.988	0.605	0.279	0.324
R^2	0.115	1.616	6.210	7.851	7.976
L					
RC	0.007	0.206	0.414	0.932	1.019
	0.790	0.079	0.088	0.075	0.181
R^2	2.039	8.451	11.053	13.723	15.439

Table B3 Predictive: PVGO Proxies – Changes – with Volatility Controls

The table reports the slopes and the R^2 of the predictive regressions of future (log) changes of common proxies for the present value of growth options over a future horizon of 30, 91, 182, 273, and 365 calendar days on implied correlations (IC) (and its lagged values) from matching-maturity options calculated for the S&P 500, the realized index variance (RV) of the S&P 500, and as a proxy for idiosyncratic risk the value-weighted sum of squared residuals ($VWIV$), calculated from a CAPM model for the whole CRSP universe. The sample period ranges from 01/1996 to 12/2020. The data is sampled on a monthly frequency. The proxies for PVGO include the ratio of the market value to book value of assets (M/B), an estimate of Tobin's Q (Q), the debt to equity ratio (DTE), and the ratio of capital expenditures to fixed assets ($CAPEX$). The data for the calculation of the PVGO proxies is obtained from Compustat and available on a monthly frequency. For further details see Appendix A.

	30 days		91 days		182 days		273 days		365 days	
M/B										
IC	0.003	0.029	0.256	0.220	0.827	0.726	1.049	0.859	1.079	0.834
	0.987	0.864	0.058	0.091	0.001	0.001	0.001	0.001	0.026	0.039
RV	0.160	-	0.009	-	-0.127	-	-0.398	-	-0.746	-
	0.172	-	0.970	-	0.573	-	0.299	-	0.089	-
$VWIV$	-	-0.061	-	-0.140	-	-0.222	-	-0.341	-	-0.422
	-	0.474	-	0.030	-	0.035	-	0.029	-	0.035
R^2	-0.428	-0.464	8.662	10.656	14.355	16.791	15.684	19.300	19.812	23.271
Q										
IC	0.110	0.132	0.395	0.350	0.889	0.775	1.214	0.995	1.288	1.000
	0.594	0.510	0.028	0.046	0.008	0.016	0.000	0.001	0.016	0.024
RV	0.140	-	-0.030	-	-0.109	-	-0.450	-	-0.885	-
	0.312	-	0.914	-	0.670	-	0.317	-	0.084	-
$VWIV$	-	-0.069	-	-0.159	-	-0.256	-	-0.394	-	-0.494
	-	0.456	-	0.028	-	0.031	-	0.024	-	0.027
R^2	-0.419	-0.390	8.255	10.063	13.712	16.098	15.415	19.029	19.451	22.982
DTE										
IC	0.707	0.671	-0.114	-0.133	-0.447	-0.521	-0.631	-0.707	-0.462	-0.545
	0.024	0.026	0.355	0.276	0.034	0.013	0.020	0.015	0.076	0.043
RV	-0.188	-	-0.160	-	-0.654	-	-0.900	-	-1.093	-
	0.483	-	0.535	-	0.002	-	0.004	-	0.025	-
$VWIV$	-	0.013	-	-0.012	-	-0.057	-	-0.067	-	-0.068
	-	0.924	-	0.828	-	0.569	-	0.639	-	0.704
R^2	0.462	0.388	5.669	5.222	11.479	8.739	10.135	7.162	10.007	6.987
$CAPEX$										
IC	-0.531	-0.499	-0.497	-0.533	0.031	-0.010	0.675	0.643	0.539	0.516
	0.035	0.043	0.150	0.119	0.953	0.986	0.185	0.199	0.005	0.017
RV	0.174	-	-0.245	-	-0.257	-	-0.849	-	-1.182	-
	0.190	-	0.659	-	0.618	-	0.046	-	0.004	-
$VWIV$	-	-0.022	-	-0.041	-	-0.050	-	0.016	-	0.060
	-	0.845	-	0.756	-	0.742	-	0.908	-	0.668
R^2	0.328	0.234	-0.122	-0.197	-0.963	-1.000	0.421	-0.158	11.974	8.280

Table B4 Predictive: Factor Returns with Volatility Controls

The table shows the slope and the R^2s of the regressions of the excess market and value factor returns realized over a future horizon of 30, 91, 182, 273, and 365 calendar days on implied correlations (IC) (and its lagged values) from matching-maturity options calculated for the S&P 500, the realized index variance (RV) of the S&P 500, and as a proxy for idiosyncratic risk the value-weighted sum of squared residuals ($VWIV$), calculated from a CAPM model for the whole CRSP universe. The sample period is from 01/1996 to 12/2020, and the variables are sampled on monthly frequency. The market neutral returns are estimated applying equation (18) to the factor data, which is obtained from Kenneth French's website. The intercept is not shown. The p-values (under the slope) are computed with Newey and West (1987) standard errors.

	Return, 30 days		Return, 91 days		Return, 182 days		Return, 273 days		Return, 365 days	
MKTRF										
IC	0.004	-0.006	0.168	0.151	0.428	0.437	0.791	0.799	0.776	0.753
	0.931	0.874	0.004	0.015	0.000	0.000	0.000	0.000	0.000	0.000
RV	-0.037	-	-0.105	-	0.383	-	0.776	-	0.712	-
	0.665	-	0.586	-	0.070	-	0.006	-	0.099	-
VWIV	-	-0.028	-	-0.030	-	-0.034	-	-0.061	-	-0.102
	-	0.087	-	0.416	-	0.642	-	0.595	-	0.504
R^2	4.433	5.112	16.336	16.156	24.704	22.494	27.631	23.200	23.703	22.309
HML										
IC	-0.037	-0.037	-0.152	-0.134	-0.372	-0.262	-0.486	-0.269	-0.631	-0.340
	0.130	0.099	0.010	0.012	0.003	0.010	0.019	0.064	0.066	0.192
RV	-0.024	-	-0.123	-	0.360	-	0.863	-	1.034	-
	0.358	-	0.212	-	0.069	-	0.000	-	0.004	-
VWIV	-	0.044	-	0.113	-	0.220	-	0.340	-	0.450
	-	0.001	-	0.000	-	0.001	-	0.001	-	0.002
R^2	2.241	7.054	8.538	15.817	12.381	21.177	19.385	27.337	20.310	33.039
*HML**										
IC	-0.014	-0.017	-0.123	-0.122	-0.331	-0.279	-0.414	-0.288	-0.428	-0.250
	0.533	0.439	0.028	0.026	0.004	0.010	0.016	0.048	0.066	0.193
RV	-0.031	-	-0.211	-	-0.111	-	0.185	-	0.076	-
	0.279	-	0.000	-	0.435	-	0.584	-	0.829	-
VWIV	-	0.029	-	0.075	-	0.146	-	0.228	-	0.322
	-	0.006	-	0.008	-	0.019	-	0.022	-	0.019
R^2	2.310	4.479	10.411	10.613	8.422	13.786	9.453	17.334	10.290	22.111

Table B5 Predictive: Factor Returns with PVGO Controls

The table shows the slope and the R^2s of the regressions of the excess market and value factor returns realized over a future horizon of 30, 91, 182, 273, and 365 calendar days on implied correlations (IC) (and its lagged values) for the S&P 500 index controlling for PVGO proxies: the ratio of the market value to book value of assets (M/B), an estimate of Tobin's Q (Q), the debt to equity ratio (DTE), and the ratio of capital expenditures to fixed assets ($CAPEX$). The data for the calculation of the proxies is obtained from Compustat and available on a monthly frequency. For further details, see Appendix A. The sample period is from 01/1996 to 12/2020, and the variables are sampled monthly. The market-neutral returns are estimated applying equation (18) to the factor data, which is obtained from Kenneth French's website. The intercept is not shown. The p-values (under the slope) are computed with Newey and West (1987) standard errors.

	Return, 30 days		Return, 91 days		Return, 182 days		Return, 273 days		Return, 365 days	
MKTRF										
IC	-0.001	-0.001	0.167	0.165	0.470	0.467	0.799	0.795	0.636	0.629
	0.980	0.975	0.009	0.009	0.000	0.000	0.000	0.000	0.001	0.001
M/B	0.002	-	0.003	-	0.006	-	0.005	-	-0.004	-
	0.296	-	0.328	-	0.251	-	0.479	-	0.614	-
Q	-	0.002	-	0.003	-	0.006	-	0.005	-	-0.005
	-	0.332	-	0.421	-	0.294	-	0.524	-	0.554
DTE	0.027	0.025	0.073	0.069	0.226	0.219	0.328	0.321	0.435	0.436
	0.544	0.576	0.180	0.206	0.003	0.004	0.001	0.001	0.002	0.001
$CAPEX$	-0.075	-0.073	-0.035	-0.029	-0.009	-0.004	-0.274	-0.269	-0.290	-0.285
	0.262	0.272	0.691	0.738	0.940	0.974	0.177	0.185	0.229	0.236
R^2	4.708	4.656	15.617	15.501	23.841	23.745	25.880	25.823	26.315	26.362
HML										
IC	-0.037	-0.038	-0.136	-0.137	-0.259	-0.267	-0.226	-0.237	-0.209	-0.221
	0.132	0.126	0.009	0.009	0.011	0.009	0.061	0.051	0.208	0.178
M/B	0.001	-	0.004	-	0.010	-	0.020	-	0.029	-
	0.560	-	0.448	-	0.163	-	0.054	-	0.039	-
Q	-	0.001	-	0.003	-	0.009	-	0.018	-	0.027
	-	0.628	-	0.517	-	0.239	-	0.105	-	0.077
DTE	-0.041	-0.043	0.010	0.005	0.055	0.042	0.116	0.094	0.155	0.124
	0.162	0.145	0.838	0.917	0.480	0.579	0.251	0.345	0.248	0.344
$CAPEX$	0.020	0.022	0.139	0.145	0.158	0.171	0.278	0.296	0.408	0.429
	0.694	0.664	0.077	0.066	0.286	0.248	0.124	0.101	0.073	0.057
R^2	3.061	2.977	9.343	9.146	12.514	11.997	18.856	18.046	25.841	24.965
*HML**										
IC	-0.019	-0.020	-0.129	-0.131	-0.280	-0.286	-0.276	-0.285	-0.186	-0.195
	0.411	0.396	0.020	0.019	0.017	0.015	0.052	0.044	0.213	0.188
M/B	0.000	-	0.000	-	0.005	-	0.009	-	0.012	-
	0.893	-	0.987	-	0.406	-	0.236	-	0.273	-
Q	-	0.000	-	-0.000	-	0.004	-	0.008	-	0.010
	-	0.968	-	0.926	-	0.529	-	0.338	-	0.356
DTE	-0.042	-0.043	-0.031	-0.032	-0.041	-0.048	-0.025	-0.036	-0.020	-0.034
	0.086	0.078	0.471	0.445	0.575	0.508	0.802	0.708	0.874	0.787
$CAPEX$	0.030	0.031	0.182	0.186	0.202	0.210	0.278	0.290	0.475	0.488
	0.431	0.404	0.025	0.022	0.223	0.203	0.143	0.127	0.047	0.042
R^2	2.730	2.715	8.493	8.501	9.922	9.743	12.186	11.864	16.206	15.906

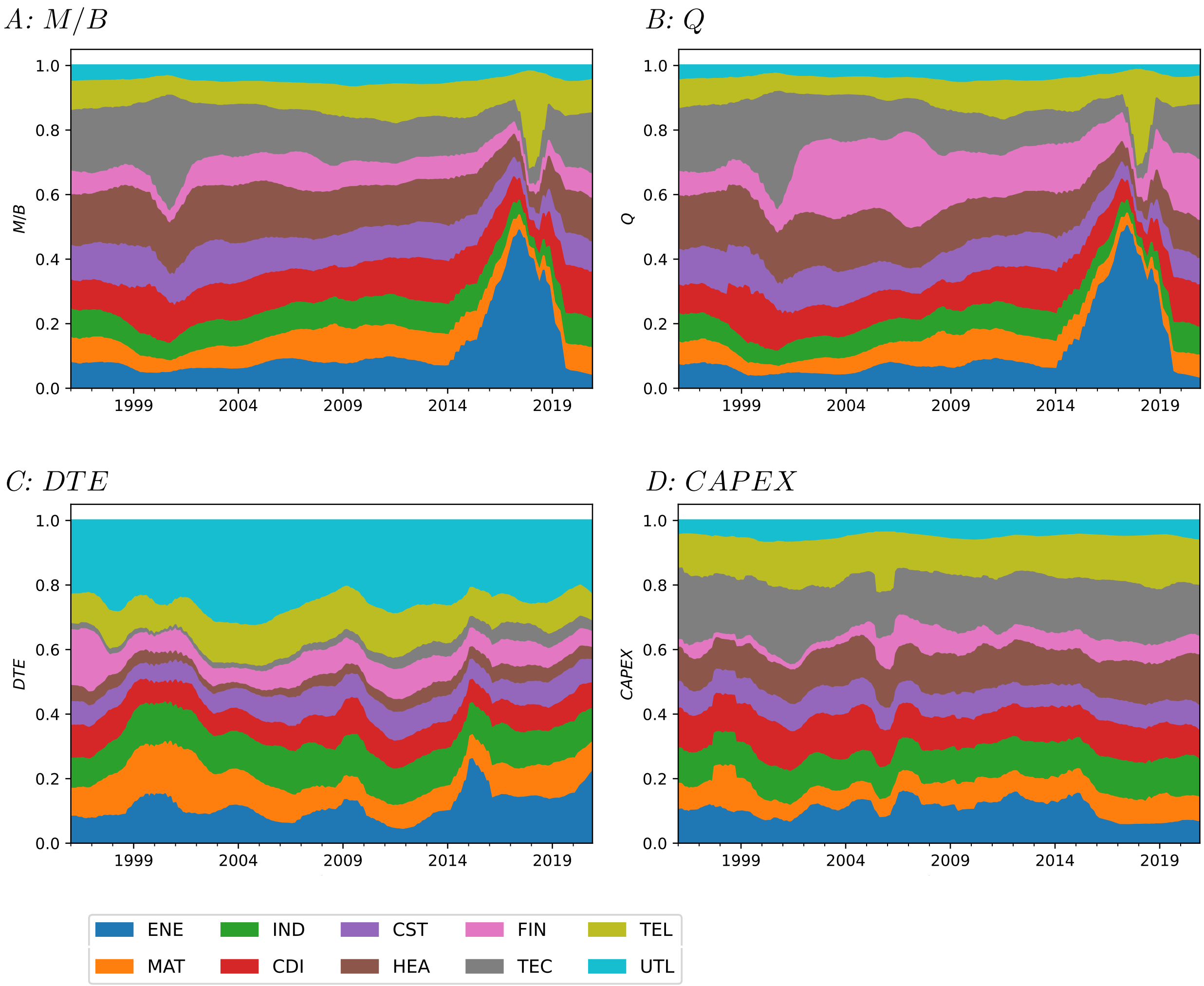
Table B6 Predictive: Factor Returns with Controls

The table shows the slope and the R^2s of the regressions of the excess market and value factor returns realized over a future horizon of 30, 91, 182, 273, and 365 calendar days on implied correlations (IC) (and its lagged values) for the S&P 500 Index. The sample period is from 01/1996 to 12/2020, and the variables are sampled monthly. The Earnings Price Ratio (EP), the Term Spread (TMS), the Default Yield Spread (DFY), the Book-to-Market Ratio (B/M), and the Net Equity Expansion (NTIS) are constructed from the data and the procedures from the study of Goyal and Welch (2008). The market neutral returns are estimated applying equation (18) to the factor data, which is obtained from Kenneth French's website. The intercept is not shown. The p-values (under the slope) are computed with Newey and West (1987) standard errors.

	Return, 30 days		Return, 91 days		Return, 182 days		Return, 273 days		Return, 365 days	
MKTRF										
IC	0.013	-0.009	0.209	0.143	0.553	0.388	0.921	0.689	0.847	0.608
	0.739	0.818	0.000	0.024	0.000	0.000	0.000	0.000	0.000	0.003
$EP12$	-0.004	-	-0.028	-	-0.068	-	-0.067	-	-0.027	-
	0.627	-	0.156	-	0.048	-	0.148	-	0.603	-
TMS	-0.337	-	-1.034	-	-1.859	-	-1.773	-	-1.099	-
	0.141	-	0.035	-	0.050	-	0.194	-	0.537	-
DFY	-1.634	-	-3.810	-	-3.242	-	-0.982	-	2.597	-
	0.130	-	0.158	-	0.402	-	0.833	-	0.604	-
BM	-	0.036	-	0.067	-	0.217	-	0.400	-	0.610
	-	0.400	-	0.452	-	0.165	-	0.075	-	0.048
$NTIS$	-	0.157	-	0.581	-	1.282	-	1.852	-	2.184
	-	0.395	-	0.263	-	0.183	-	0.173	-	0.185
R^2	5.821	4.250	20.637	17.194	27.787	26.194	25.495	28.460	22.156	28.309
HML										
IC	-0.040	-0.039	-0.162	-0.156	-0.362	-0.355	-0.509	-0.504	-0.713	-0.668
	0.096	0.103	0.004	0.007	0.003	0.005	0.015	0.017	0.041	0.048
$EP12$	-0.009	-	-0.022	-	-0.023	-	0.001	-	0.037	-
	0.167	-	0.206	-	0.503	-	0.982	-	0.514	-
TMS	0.192	-	0.514	-	0.730	-	1.170	-	2.268	-
	0.214	-	0.204	-	0.425	-	0.405	-	0.186	-
DFY	-0.792	-	-0.946	-	0.942	-	3.755	-	6.276	-
	0.350	-	0.654	-	0.781	-	0.338	-	0.175	-
BM	-	-0.028	-	-0.050	-	0.009	-	0.160	-	0.252
	-	0.365	-	0.537	-	0.958	-	0.503	-	0.382
$NTIS$	-	0.037	-	0.155	-	0.302	-	0.623	-	1.163
	-	0.732	-	0.592	-	0.570	-	0.405	-	0.236
R^2	2.670	2.045	9.019	7.596	11.325	9.536	14.386	12.660	19.429	16.608
*HML**										
IC	-0.018	-0.019	-0.140	-0.133	-0.345	-0.323	-0.459	-0.424	-0.531	-0.458
	0.433	0.421	0.022	0.021	0.007	0.009	0.010	0.017	0.025	0.035
$EP12$	-0.000	-	-0.000	-	0.005	-	0.030	-	0.062	-
	0.980	-	0.992	-	0.873	-	0.487	-	0.204	-
TMS	0.183	-	0.498	-	0.834	-	1.311	-	2.331	-
	0.225	-	0.260	-	0.402	-	0.365	-	0.183	-
DFY	-0.947	-	-1.910	-	-2.814	-	-1.940	-	-1.250	-
	0.139	-	0.208	-	0.311	-	0.572	-	0.770	-
BM	-	-0.019	-	-0.065	-	-0.076	-	0.021	-	0.093
	-	0.443	-	0.365	-	0.652	-	0.928	-	0.739
$NTIS$	-	0.093	-	0.217	-	0.479	-	0.908	-	1.654
	-	0.432	-	0.510	-	0.410	-	0.272	-	0.106
R^2	2.709	2.061	7.862	7.445	9.525	9.116	11.072	10.728	14.800	14.481

Figure B3. PVGO Proxies: Sector Exposure

The figure shows the exposure of common proxies for the value of growth options. The sample period ranges from 01/1996 to 12/2020. The proxies for PVGO include the ratio of the market value to book value of assets (M/B), an estimate of Tobin's Q (Q), the debt to equity ratio (DTE), and the ratio of capital expenditures to fixed assets ($CAPEX$). The growth options are classified via the sector information based on GICS codes and weighted according to the market capitalization of the respective company. The data for the calculation of the PVGO proxies is obtained from Compustat and available on a monthly frequency. For further details see Appendix A. In the plots the twelve months moving average is depicted.



Appendix C. Internet Appendix

Appendix C.1. The Model

In this part some derivations and equations stated in the main text are derived and explained in more detail.

Appendix C.1.1. Assets in Place

The time-t market value of an existing project j, $p(\varepsilon_{ft}, u_{jt}, x_t, K_j)$ is equal to the present value of its cash flows,

$$p(\varepsilon_{ft}, u_{jt}, x_t, K_j) = \mathrm{E}_t[\int_t^{\infty} e^{-\delta(s-t)} \frac{\pi_s}{\pi_t} y_{fjs} ds] = \mathrm{E}_t[\int_t^{\infty} e^{-\delta(s-t)} \frac{\pi_s}{\pi_t} \varepsilon_{fs} u_{js} x_s K_j^{\alpha} ds] = A(\varepsilon_{ft}, u_{jt}) x_t K_j^{\alpha}, \tag{C1}$$

where

$$A(\varepsilon, u) = \frac{1}{r + \gamma_x \sigma_x + \delta - \mu_x} + \frac{1}{r + \gamma_x \sigma_x + \delta - \mu_x + \theta_{\varepsilon}} (\varepsilon - 1) + \frac{1}{r + \gamma_x \sigma_x + \delta - \mu_x + \theta_u} (u - 1)$$
$$+ \frac{1}{r + \gamma_x \sigma_x + \delta - \mu_x + \theta_{\varepsilon} + \theta_u} (\varepsilon - 1)(u - 1).$$

Appendix C.1.2. Optimal Investment

The optimal investment K_j of firm f in project j at time t is given by $K_f = (z_t \alpha A(\epsilon_{f_t}, 1))^{\frac{1}{1-\alpha}}$. K_f is the solution to the problem

$$\max_{K_f} A(\epsilon_{f_t}, 1) x_t K_f^{\alpha} - z_t^{-1} x_t K_f. \tag{C2}$$

Rearranging the the first-order condition leads to the optimal solution

$$0 = \frac{\partial}{\partial K_f} [A(\epsilon_{f_t}, 1) x_t K_f^{\alpha} - z_t^{-1} x_t K_f] = \alpha A(\epsilon_{f_t}, 1) K_f^{\alpha - 1} - z_t^{-1} \quad \Rightarrow \quad K_f = (z_t \alpha A(\epsilon_{f_t}, 1))^{\frac{1}{1-\alpha}}.$$

Appendix C.1.3. The Value of Growth Opportunities

The NPV of future projects determines the value of growth opportunities. The value added net of investment costs, when a project is financed is

$$K_f A(\epsilon_{f_t},1)x_t - \frac{K_f x_t}{z_t} = [\alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}}] z_t^{\frac{\alpha}{1-\alpha}} x_t A(\epsilon_{f_t},1)^{\frac{1}{1-\alpha}} = C z_t^{\frac{\alpha}{1-\alpha}} x_t A(\epsilon_{f_t},1)^{\frac{1}{1-\alpha}}.$$

The present value of growth options can then be written as

$$\begin{aligned} PVGO_{ft} &= \mathrm{E}_t^{\mathbb{Q}}[\int_t^\infty e^{-r(s-t)} \lambda_{fs} C z_t^{\frac{\alpha}{1-\alpha}} x_t A(\epsilon_{f_t},1)^{\frac{1}{1-\alpha}} ds] \\ &= C z_t^{\frac{\alpha}{1-\alpha}} x_t \mathrm{E}_t[\int_t^\infty e^{-\rho(s-t)} \lambda_{fs} A(\epsilon_{f_t},1)^{\frac{1}{1-\alpha}} ds] \\ &= C z_t^{\frac{\alpha}{1-\alpha}} x_t G(\varepsilon_{ft}, \lambda_{ft}), \end{aligned} \tag{C3}$$

where E_t^Q denotes the expectations under the risk-neutral measure $\mathbb{Q}$.

$$\begin{aligned} G_{ft} := G(\varepsilon_{ft}, \lambda_{ft}) &= C \cdot \mathrm{E}_t[\int_t^\infty e^{-\rho(s-t)} \lambda_{fs} A(\varepsilon_{fs})^{\frac{1}{1-\alpha}} ds] \\ &= \begin{cases} \lambda_f(G_1(\varepsilon_{ft}) + \frac{\mu_L}{\mu_L+\mu_H}(\lambda_H - \lambda_L) G_2(\varepsilon_{ft})) & \bar{\lambda}_{ft} = \lambda_H \\ \lambda_f(G_1(\varepsilon_{ft}) - \frac{\mu_H}{\mu_L+\mu_H}(\lambda_H - \lambda_L) G_2(\varepsilon_{ft})) & \bar{\lambda}_{ft} = \lambda_L, \end{cases} \end{aligned} \tag{C4}$$

with $\rho = r + \gamma_x\sigma_x - \mu_x - \frac{\alpha}{1-\alpha}(\mu_z - \gamma_z\sigma_z + \frac{1}{2}\sigma_z^2) - \frac{\alpha^2\sigma_z^2}{2(1-\alpha)^2}$, and $C = \alpha^{\frac{1}{1-\alpha}}(\alpha^{-1} - 1)$. An application of the Feynman–Kac formula states that $G_1(\varepsilon)$ and $G_2(\varepsilon)$ solve the following ODE:

$$a(\varepsilon)z' - b(\varepsilon)z - \rho_i y + c(\varepsilon) = 0,$$

where $a(\varepsilon) = \frac{1}{2}\sigma_\varepsilon^2\varepsilon, b(\varepsilon) = \theta_\varepsilon(\varepsilon - 1), c(\varepsilon) = CA(\varepsilon,1)^{\frac{1}{1-\alpha}}, y = G, z = G'$, and $\rho_1 = \rho, \rho_2 = \rho + \mu_H + \mu_L$. For further details, see Kogan and Papanikolaou (2014).

Appendix C.1.4. Value and Growth Dynamics

The dynamics of value of assets in place can be written as (for notational convenience define $\sum_j A_{ft} := \sum_{j \in J_t^f} A(\varepsilon_{ft}, u_{jt}) K_j^\alpha$ and $G_{ft} := G(\varepsilon_{ft}, \lambda_{ft})$).

$$dVAP_{ft} = dx_t \sum_j A_{ft} + x_t d \sum_j A_{ft} + dx_t d \sum_j A_{ft} = dx_t \sum_j A_{ft} + x_t d \sum_j A_{ft}, \tag{C5}$$

and, therefore,

$$\frac{dVAP_{ft}}{VAP_{ft}} = \frac{dx_t}{x_t} \frac{\sum_j A_{ft}}{\sum_j A_{ft}} + \frac{x_t}{x_t} \frac{d \sum_j A_{ft}}{\sum_j A_{ft}} = \frac{dx_t}{x_t} + \frac{d \sum_j A_{ft}}{\sum_j A_{ft}}. \tag{C6}$$

The dynamics of the present value of growth options can be written as

$$dPVGO_{ft} = d(z_t^{\frac{\alpha}{1-\alpha}} x_t G_{ft}) = d(z_t^{\frac{\alpha}{1-\alpha}} x_t) G_{ft} + z_t^{\frac{\alpha}{1-\alpha}} x_t dG_{ft} + d(z_t^{\frac{\alpha}{1-\alpha}} x_t) dG_{ft}. \tag{C7}$$

First, calculate

$$\begin{aligned} d(z_t^{\frac{\alpha}{1-\alpha}} x_t) &= z_t^{\frac{\alpha}{1-\alpha}} dx_t + x_t d(z_t^{\frac{\alpha}{1-\alpha}}) + d[x_t, z_t^{\frac{\alpha}{1-\alpha}}] \\ &= z_t^{\frac{\alpha}{1-\alpha}} dx_t + x_t \frac{\alpha}{1-\alpha} z_t^{\frac{\alpha}{1-\alpha}-1} dz_t + x_t \frac{1}{2} \frac{\partial^2 z_t^{\frac{\alpha}{1-\alpha}}}{\partial z^2} \sigma_z^2 z_t^2 dt \\ &= z_t^{\frac{\alpha}{1-\alpha}} dx_t + x_t \frac{\alpha}{1-\alpha} z_t^{\frac{\alpha}{1-\alpha}-1} dz_t + x_t R(z_t) dt, \end{aligned}$$

and, therefore,

$$dPVGO_{ft} = (z_t^{\frac{\alpha}{1-\alpha}} dx_t + x_t \frac{\alpha}{1-\alpha} z_t^{\frac{\alpha}{1-\alpha}-1} dz_t + x_t R(z_t) dt) G_{ft} + z_t^{\frac{\alpha}{1-\alpha}} x_t dG_{ft}. \tag{C8}$$

In relative terms, one obtains

$$\begin{aligned} \frac{dPVGO_{ft}}{PVGO_{ft}} &= \frac{z_t^{\frac{\alpha}{1-\alpha}} dx_t}{z_t^{\frac{\alpha}{1-\alpha}} x_t} + \frac{x_t \frac{\alpha}{1-\alpha} z_t^{\frac{\alpha}{1-\alpha}-1} dz_t}{z_t^{\frac{\alpha}{1-\alpha}} x_t} + \frac{R(z_t) dt}{z_t^{\frac{\alpha}{1-\alpha}}} + \frac{z_t^{\frac{\alpha}{1-\alpha}} x_t dG_{ft}}{z_t^{\frac{\alpha}{1-\alpha}} x_t G_{ft}} \\ &= \frac{dx_t}{x_t} + \frac{\alpha}{1-\alpha} \frac{dz_t}{z_t} + \frac{R(z_t) dt}{z_t^{\frac{\alpha}{1-\alpha}}} + \frac{dG_{ft}}{G_{ft}}. \end{aligned} \tag{C9}$$

Appendix C.1.5. Expected Returns Dynamics

The risk premium on VAP and $PVGO$ is given by the covariance of the pricing kernel $\frac{d\pi_t}{\pi_t} = -rdt - \gamma_x dB_{xt} - \gamma_z dB_{zt}$ and the respective expressions (C6) and (C9),

$$\mathrm{E}_t[R_{ft}^{VAP}] - r_f = -cov(\frac{dVAP_{ft}}{VAP_{ft}}, \frac{d\pi_t}{\pi_t}) = -cov(\frac{dx_t}{x_t}, \frac{d\pi_t}{\pi_t}) = \sigma_x \gamma_x dt, \tag{C10}$$

and

$$\mathrm{E}_t[R_{ft}^{GO}] - r_f = -cov(\frac{dPVGO_{ft}}{PVGO_{ft}}, \frac{d\pi_t}{\pi_t}) = -cov(\frac{dx_t}{x_t} + \frac{\alpha}{1-\alpha}\frac{dz_t}{z_t}, \frac{d\pi_t}{\pi_t}) = \sigma_x \gamma_x dt + \frac{\alpha}{1-\alpha}\sigma_z \gamma_z dt. \tag{C11}$$

Hence,

$$\begin{aligned}\mathrm{E}_t[R_{ft}] - r_f &= \frac{VAP_{ft}}{V_t}(\mathrm{E}_t[R_{ft}^{VAP}] - r_f) + \frac{PVGO_{ft}}{V_t}(\mathrm{E}_t[R_{ft}^{GO}] - r_f) \\ &= \frac{VAP_{ft}}{V_t}(\sigma_x\gamma_x) + \frac{PVGO_{ft}}{V_t}(\sigma_x\gamma_x + \frac{\alpha}{1-\alpha}\sigma_z\gamma_z) \\ &= \sigma_x\gamma_x + \frac{\alpha}{1-\alpha}\sigma_z\gamma_z\frac{PVGO_{ft}}{V_t}. \end{aligned} \tag{C12}$$

Appendix C.1.6. Market Return Dynamics

To aggregate the individual components into the market index, it is assumed that constituents are value-weighted; hence, $V_{it}/\sum V_{it} := V_{it}/V_{Mt}$. The market return can be written as

$$\sum_f \frac{1}{dt}\frac{V_{ft}}{V_{Mt}} E[R_{ft}] - r_f = \sum_f \frac{V_{ft}}{V_{Mt}}\gamma_x\sigma_x + \frac{\alpha}{1-\alpha}\gamma_z\sigma_z \sum_f \frac{V_{ft}}{V_{Mt}}\frac{PVGO_{ft}}{V_{ft}} = \gamma_x\sigma_x + \frac{\alpha}{1-\alpha}\gamma_z\sigma_z\frac{PVGO_{Mt}}{V_{Mt}}, \tag{C13}$$

where $PVGO_M := \sum_f PVGO_f$. The market return variance can be written as

$$\begin{aligned}\sum_k\sum_l w_k w_l dR_{kt} dR_{lt} &= \sum_k\sum_l \frac{V_{kt}}{V_{Mt}}\frac{V_{lt}}{V_{Mt}}\sigma_x^2 dt + (\frac{\alpha}{1-\alpha})^2\sigma_z^2 \sum_k\sum_l \frac{V_{kt}}{V_{Mt}}\frac{V_{lt}}{V_{Mt}}\frac{PVGO_{kt}}{V_{kt}}\frac{PVGO_{lt}}{V_{lt}}dt \\ &= \sum_k\sum_l \frac{V_{kt}}{V_{Mt}}\frac{V_{lt}}{V_{Mt}}\sigma_x^2 dt + (\frac{\alpha}{1-\alpha})^2\sigma_z^2 \sum_k\sum_l \frac{PVGO_{kt}}{V_{Mt}}\frac{PVGO_{lt}}{V_{Mt}}dt\end{aligned}$$

$$= \sigma_x^2 dt + (\frac{\alpha}{1-\alpha})^2 \sigma_z^2 (\frac{PVGO_{Mt}}{V_{Mt}})^2 dt, \tag{C14}$$

where the last step follows with $\sum_k \sum_l \frac{V_{kt}}{V_{Mt}} \frac{V_{lt}}{V_{Mt}} = 1$, and $PVGO_M^2 := (\sum_k PVGO_k)^2 = \sum_k \sum_l PVGO_k PVGO_l$.

Appendix C.1.7. Firm Return Dynamics

The dynamics for the changes in firm value can be calculated as follows:

$$\begin{aligned}
dV_{ft} &= dVAP_{ft} + dPVGO_{ft} \\
&= \sum_j A_{ft} dx_t + x_t d \sum_j A_{ft} + (z_t^{\frac{\alpha}{1-\alpha}} dx_t + x_t \frac{\alpha}{1-\alpha} z_t^{\frac{\alpha}{1-\alpha}-1} dz_t + R(z_t)dt) G_{ft} + z_t^{\frac{\alpha}{1-\alpha}} x_t dG_{ft} \\
&= R(z_t) G_{ft} dt + (\sum_j A_{ft} + z_t^{\frac{\alpha}{1-\alpha}} G_{ft}) dx_t + x_t \frac{\alpha}{1-\alpha} z_t^{\frac{\alpha}{1-\alpha}-1} G_{ft} dz_t + x_t d \sum_j A_{ft} + z_t^{\frac{\alpha}{1-\alpha}} x_t dG_{ft} \\
&= \bar{R}(z_t) dt + \sigma_x dB_{xt} (x_t \sum_j A_{ft} + x_t z_t^{\frac{\alpha}{1-\alpha}} G_{ft}) + x_t z_t^{\frac{\alpha}{1-\alpha}} G_{ft} \frac{\alpha}{1-\alpha} \sigma_z dB_{zt} + dIdio_f \\
&= \bar{R}(z_t) dt + \sigma_x dB_{xt} V_{ft} + \frac{\alpha}{1-\alpha} PVGO_{ft} \sigma_z dB_{zt} + dIdio_f,
\end{aligned} \tag{C15}$$

where

$$dIdio_f = x_t d \sum_j A_{ft} + z_t^{\frac{\alpha}{1-\alpha}} x_t dG_{ft} \tag{C16}$$

denotes the dynamics associated with A_{ft} (as a function of $\varepsilon_{ft}, u_{jt}, K_j^\alpha$) and G_{ft}. The return dynamic of the firm can be written as

$$dR_{ft} = \frac{dV_{ft}}{V_{ft}} = \mathrm{E}[R_{ft}]dt + \sigma_x dB_{xt} + \frac{\alpha}{1-\alpha} \frac{PVGO_{ft}}{V_{ft}} \sigma_z dB_{zt} + \frac{dIdio_f}{V_{ft}}. \tag{C17}$$

Since idiosyncratic terms are uncorrelated, one can calculate the covariance between two returns as follows:

$$\begin{aligned}
dR_{kt} dR_{lt} = &(\mathrm{E}[R_{kt}]dt + \sigma_x dB_{xt} + \frac{\alpha}{1-\alpha} \sigma_z \frac{PVGO_{kt}}{V_{kt}} dB_{zt} + \frac{dIdio_k}{V_{kt}}) \\
&\times (\mathrm{E}[R_{lt}]dt + \sigma_x dB_{xt} + \frac{\alpha}{1-\alpha} \sigma_z \frac{PVGO_{lt}}{V_{lt}} dB_{zt} + \frac{dIdio_l}{V_{lt}})
\end{aligned}$$

$$= \sigma_x^2 dt + (\frac{\alpha}{1-\alpha})^2 \sigma_z^2 \frac{PVGO_{kt}}{V_{kt}} \frac{PVGO_{lt}}{V_{lt}} dt. \tag{C18}$$

The variance of the return process $\sigma^2(dR_{ft})$ is given by

$$dR_{ft}dR_{ft} = (\mathrm{E}[R_f]dt + \sigma_x dB_{xt} + \frac{\alpha}{1-\alpha}\sigma_z \frac{PVGO_{ft}}{V_{ft}} dB_{zt} + \frac{dIdio_f}{V_f})^2$$

$$= \sigma_x^2 dt + (\frac{\alpha}{1-\alpha})^2 \sigma_z^2 (\frac{PVGO_{ft}}{V_{ft}})^2 dt + (\frac{dIdio_f}{V_{ft}})^2. \tag{C19}$$

Therefore, the correlation can be calculated as

$$Corr(dR_{kt}, dR_{lt}) = \frac{dR_{kt}dR_{lt}}{\sqrt{\sigma^2(dR_{kt})}\sqrt{\sigma^2(dR_{lt})}}$$

$$= \frac{\sigma_x^2 dt + (\frac{\alpha}{1-\alpha})^2 \sigma_z^2 \frac{PVGO_{kt}}{V_{kt}} \frac{PVGO_{lt}}{V_{lt}} dt}{\sqrt{\sigma_x^2 dt + (\frac{\alpha}{1-\alpha})^2 \sigma_z^2 (\frac{PVGO_{kt}}{V_{kt}})^2 dt + (\frac{dIdio_k}{V_{kt}})^2}\sqrt{\sigma_x^2 dt + (\frac{\alpha}{1-\alpha})^2 \sigma_z^2 (\frac{PVGO_{lt}}{V_{lt}})^2 dt + (\frac{dIdio_l}{V_{lt}})^2}}. \tag{C20}$$

Appendix C.2. NBER Recession Indicator - Contraction and Expansion

The time series is composed of dummy variables that represent periods recession (1) and expansion (0). The recession begins on the first day of the period following a peak and ends on the last day of the period of the trough. The NBER defines the contraction periods (peak to trough) as displayed in the table. The rest of the time is defined as expansion.

Table C7 NBER - Contraction and Expansion Periods

Peak	Trough	Lenght
1957-08	1958-04	8
1960-04	1961-02	10
1969-12	1970-11	11
1973-11	1975-03	16
1980-01	1980-07	6
1981-07	1982-11	16
1990-07	1991-03	8
2001-03	2001-11	8
2007-12	2009-06	18
2020-02	2020-04	2

Figure C4. Recession Indicator – Contraction and Expansion

The figure shows the Contraction and Expansion periods as defined by NBER from the period of 1957 to 2018. Contraction periods are characterized by the bars equal to 1. By definition, not being in contraction means that the economy is situated in expansion.