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MODELLING EQUITY MARKET TERM STRUCTURES

DISCUSSION NOTE

We outline a present-value modelling approach for estimating term structures of expected dividend growth and risk premiums in equity markets. We apply our methodology to equity markets in the US, euro area, Japan and UK.

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SUMMARY

- We outline a methodology for estimating term structures of expected dividend growth and risk premiums, which we apply to equity markets in the US, euro area, Japan, and the UK. These term structures are key inputs when estimating expected returns on the market and decomposing equity price movements.
- Our estimation approach relies on the use of dividend futures prices, which provide a way to breakdown the market into value associated with fixed horizons. We combine these futures prices with stock index prices, options data, and surveys within a present-value framework, allowing us to estimate term structures that extend to long maturities.
- Our model produces dividend growth and risk premium term structures that explain high proportions of the variation in stock index prices, and closely match dividend futures prices. There is considerable cyclical variation in the expected dividend growth estimates, particularly at shorter horizons. Similarly, short-term risk premiums vary considerably more than long-horizon estimates, and increase sharply during market downturns.
- The present-value approach allows us to decompose stock market values by horizon, and indicates that the majority of the value occurs beyond ten years for all markets. This is also reflected in estimates of equity market duration, which range from 20 to 25 years for the US and Japan, and 15 to 20 years for the euro area and UK.

1. Introduction

Equity prices can be expressed in terms of expected future cash flows into the infinite future, where cash flows at each horizon are discounted to their present value. Similar to the term structure of yields for government bonds, we can define term structures for equities that describe expected dividend growth and risk premiums across different horizons. It is important to obtain accurate and timely estimates of equity term structures, as they are key inputs into our estimates of expected returns on the market and decompositions of equity price movements.

In this note, we outline a present-value approach to estimating equity term structures. Our approach relies on the use of dividend futures, prices of which are informative of the value of market dividends at fixed horizons stretching several years into the future. We combine these futures prices with stock index prices, option data and surveys within a present-value framework. This allows us to estimate expected dividend growth and risk premiums over short and long horizons. Our model produces dividend growth and risk premium term structures that match the equity index and dividend futures prices simultaneously. We apply our methodology to equity markets in the US, euro area, Japan, and the UK.

Our estimates indicate that there is considerable variation in expected dividend growth, in particular at shorter horizons, where the estimates co-move closely with the economic cycle. Similarly, our estimates of short-term risk premiums vary considerably over time, and much more than longer-horizon risk premiums.

Our modelling approach allows us to break down the sources of stock market values by horizon, and to measure equity market duration. We find that the majority of value occurs beyond ten years for all markets. On average, dividends beyond 30 years capture over half the value for the US and Japan, and around a third of the value for the euro area and UK markets. This is also reflected in measures of equity market duration, which we estimate to be between 20 and 25 years on average for the US and Japanese markets, and between 15 and 20 years for the euro area and UK.

The note proceeds as follows. In the next section, we introduce dividend futures instruments and discuss data availability and quality. In Section 3, we outline a framework for understanding how dividend futures prices relate to expected cash flows and risk premiums for the overall stock market. Section 4 describes our methodology for estimating term structures, and in Section 5 we present our estimates and decompose stock market values by horizon.

2. The Dividend Futures Market

The dividend derivatives market was established around 20 years ago as an over-the-counter (OTC) dividend swap market. The need for this market arose from banks selling structured products such as equity-linked notes that offered investors exposure to equity prices. The banks selling these products found themselves holding unwanted dividend risk on their balance sheets. Finding natural counterparties in the form of hedge funds and pension funds, the banks created a market for trading dividend swaps.

Exchange-traded dividend futures, on the other hand, were established more recently. Dividend futures are contracts that allow investors to take a position on dividends paid out in a given calendar year. They are cash-settled derivative contracts whose underlying is a "dividend point index", which measures the gross dividends declared and paid by the constituents of an equity index during a predetermined period.[1]

While the first dividend futures contracts started trading on exchanges as early as 2008, trading was mostly confined to futures based on the EURO STOXX 50 index, and dividend futures on the S&P 500 only began trading in 2015.[2] Trading in dividend futures has caught up with OTC-traded swaps, however, and today exchange-traded dividend futures are the primary instruments through which market participants gain direct exposure to corporate dividends.

Table 1 lists the dividend point indices that correspond to the equity markets included in this note. The indices are reset to zero every year in December, except for the Nikkei 225.[3] Dividend futures contracts are available in annual steps up to ten years ahead, where the longest maturity varies by market.

Table 1: Overview of equity and corresponding dividend points indices in our sample

Region	Equity index	Underlying
Euro area	EURO STOXX 50	EURO STOXX 50 Dividend Points
Japan	Nikkei 225	Nikkei Stock Average Dividend Points
United Kingdom	FTSE 100	FTSE 100 Dividend Index - RDSA Withholding*
United States	S&P 500	S&P 500 Dividend Points Annual Index

*Note: *All dividends are as declared by companies and no withholding tax adjustments are made except for dividends paid by Royal Dutch Shell. In order to comply with international treaties, a 15 percent withholding tax is deducted from dividends paid by Royal Dutch Shell A shares. For more details, see the* FTSE Russell index rules.

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[1] The buyer of a dividend derivative commits to paying the prevailing market-implied level of the dividend points index (the "fixed leg"). The seller commits to paying the dividend level that is actually realised (the "floating leg"). Payments are made only at the contract's maturity. The contracts trade in multiples of index points.

[2] See Manley and Mueller-Glissmann (2008) and Mixon and Onur (2017) for more details.

[3] Dividend futures on the Nikkei 225 index follow the financial year in Japan and expire on the last trading day of March the following calendar year.

How informative are dividend futures prices?

In this note, we use dividend futures prices to infer expected dividend growth and risk premiums at different horizons. One concern related to the use of dividend futures prices is that they might not be sufficiently informative, due to low liquidity or structural supply-demand imbalances. While recognising the possible limitations of using dividend futures prices, we nevertheless believe these instruments contain useful information about future dividend growth.

Dividend futures markets have grown substantially since their inception, as measured by the notional amounts outstanding. Near-term contracts seem to be the most liquid segment, with trading volumes declining steadily as the time to maturity increases. Arguably, these markets have been sufficiently liquid and informative in most of our sample period. This is also the conclusion of Gormsen and Koijen (2020), who argue that trading frictions do not impair the informativeness of dividend futures, for example highlighting that trading volumes actually increased during the market turmoil in the first quarter of 2020. Appendix A provides details of the liquidity and size of dividend futures markets.

Furthermore, a number of studies, such as Binsbergen, Hueskes, Koijen, and Vrugt (2013) and Gormsen and Koijen (2020), indicate that estimates of expected dividend growth extracted from dividend derivatives predict subsequently realised dividend growth, in particular at short horizons. Dividend futures prices therefore seem to contain relevant information about future dividend payouts.

3. Dividend Futures, Expected Cash Flows, and Risk Premiums

In this section, we outline how dividend futures prices relate to expected cash flows, risk premiums and the overall stock market. We often express the price of the aggregate stock market in terms of the present value of expected future cash flows. We can apply the same logic to the sum of dividends paid in a given future year from holding an equity index. The price of this "index dividend" paid out n years from now – denoted by $P_t^{(n)}$ – is the present value of the expected index dividend $E_t[D_{t+n}]$ at that point in time:

$$P_t^{(n)} = \frac{E_t[D_{t+n}]}{\exp\left(n\left(y_t^{(n)} + \theta_t^{(n)}\right)\right)}, \tag{1}$$

where $y_t^{(n)}$ is the n-year nominal yield and $\theta_t^{(n)}$ is the risk premium compensating investors for dividend risk at the n-year maturity. We can reformulate equation (1) to relate the index dividend price to expected dividend *growth* relative to the current period's index dividend D_t:

$$P_t^{(n)} = D_t \exp\left(n\left(\underbrace{g_t^{(n)}}_{\text{cash flows}}\ \underbrace{-y_t^{(n)} - \theta_t^{(n)}}_{\text{discount rate}}\right)\right). \qquad (2)$$

Here, $g_t^{(n)}$ measures the average per-period expected dividend growth rate implied by expected index dividends at different points in the future:

$$g_t^{(n)} = \frac{1}{n} E_t\left[\log\left(\frac{D_{t+n}}{D_t}\right)\right]. \qquad (3)$$

Dividend futures are quoted in terms of their *forward* prices, which are linked to index dividend prices through nominal yields under the no-arbitrage condition, which we can combine with the definition of $P_t^{(n)}$ in equation (2):

$$F_t^{(n)} = P_t^{(n)} \exp\left(ny_t^{(n)}\right) = D_t \exp\left(n\left(g_t^{(n)} - \theta_t^{(n)}\right)\right). \qquad (4)$$

This implies that in order to extract the term structures of dividend growth $g_t^{(n)}$ for the equity index, we need estimates of risk premiums $\theta_t^{(n)}$. By rearranging equation (4), we can express expected dividend growth as a function of futures prices, realised dividends and risk premiums:

$$g_t^{(n)} = \underbrace{\frac{1}{n}\log\left(\frac{F_t^{(n)}}{D_t}\right)}_{\text{Risk-neutral expected div. growth}} + \underbrace{\theta_t^{(n)}}_{\text{Risk adjustment}}. \qquad (5)$$

This equation shows that $g_t^{(n)}$ consists of two components: 1) *risk-neutral* expectations about future dividend growth and 2) the risk premium associated with the index dividend paid out n years from now. How much of the variation in the prices of dividend futures is driven by the risk premium is an empirical question.[4]

Since the value of the aggregate stock market equals the sum of discounted future dividends, the time t value of the aggregate stock market index S_t is as follows:

$$S_t = \sum_{n=1}^{\infty} P_t^{(n)}. \qquad (6)$$

The term structures for the equity market can therefore be described by the variables $g_t^{(n)}$ and $\theta_t^{(n)}$ at horizons up to infinity. We model these term structures using dividend futures prices, equity index option prices and equity indices, ensuring that they are informed by prices of traded securities.

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[4] Empirical evidence suggests that a large fraction of the variation in prices of short-horizon dividend futures is driven by changes in expected dividend growth, see Binsbergen, Hueskes, Koijen, and Vrugt (2013) and Gormsen, Koijen, and Martin (2021).

4. Term Structure Modelling Approach

In this section, we describe the data and methodology we use to model expected dividend growth and risk premium term structures. We use a present-value model that combines dividend futures prices with stock index prices, options prices, and survey data.

Present-Value Modelling of Term Structures

The present-value formula in equation (6) expresses the stock index price in terms of expected dividend growth, interest rates and risk premiums up to an infinite horizon. Dividend futures prices and other model inputs only cover horizons up to a few years, however. We utilise a present-value framework that uses relatively few assumptions to estimate full term structures that extend beyond these short horizons. We adapt the present-value formula such that the modelling of dividends and their corresponding discount rates is split into two stages:

$$S_t = \underbrace{\sum_{n=1}^{\bar{n}} P_t^{(n)}}_{\text{first stage}} + \underbrace{\overbrace{\frac{D_t \exp\left((\bar{n}+1)\, g_t^{(\bar{n}+1)}\right)}{\exp\left(\bar{y}_t + \bar{\theta}_t - \bar{g}_t\right) - 1}}^{\text{terminal value}} \overbrace{\exp\left(-(\bar{n}+1)\left(y_t^{(\bar{n}+1)} + \theta_t^{(\bar{n}+1)}\right)\right)}^{\text{discounting to present}}}_{\text{second stage}} \qquad (7)$$

where $\bar{y}_t$, $\bar{\theta}_t$, and $\bar{g}_t$ refer to terminal values of the nominal yield, risk premium and expected dividend growth.[5] In the first stage, which spans the first $\bar{n}$ years, we explicitly model each annual index dividend and discount it to the present by applying the corresponding discount rate. In the second stage, which spans the period $\bar{n}+1$ years from time t to infinity, we estimate the terminal value of all index dividends over these horizons and discount them to the present.

We represent the term structures of expected dividend growth rates $g_t^{(n)}$ and risk premiums $\theta_t^{(n)}$ at horizons from 1 to $\bar{n}$ years through a parsimonious functional form following Nelson and Siegel (1987).[6] Prices of dividend futures across maturities show a significant degree of co-movement, which indicates that both the expected dividend growth rates and risk premiums across different horizons can be represented by a small number of factors. This specification allows us to express $g_t^{(n)}$ and $\theta_t^{(n)}$ at any horizon as a function of four parameters: $g_t^{(n)}\,(\beta_{0t}^g, \beta_{1t}^g, \beta_{2t}^g, \tau_t^g)$ and $\theta_t^{(n)}\,(\beta_{0t}^\theta, \beta_{1t}^\theta, \beta_{2t}^\theta, \tau_t^\theta)$, respectively. Appendix E provides more details on the Nelson-Siegel model specification.

We use measures of all components of equation (7) as inputs into the Nelson-Siegel estimation. The first stage of our model specified in equation (7) covers the first 30 years of the term structures ($\bar{n} = 30$). This means that we explicitly model dividends and the corresponding discount rates for each year up to year 30. In addition to the index price and realised dividends, we

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[5] The second stage involves modelling a perpetuity with constant dividend growth beginning at the $\bar{n}+1$ horizon, which is then discounted to the present.

[6] The Nelson-Siegel specification is suitable as a parsimonious representation of a panel of highly correlated series. It was originally used to represent the term structure of interest rates.

combine dividend futures prices, options and yield curve data.

To obtain risk premiums at short maturities, we use options prices following the methodology outlined in Martin (2017), providing estimates up to three years ahead.[7,8] Using equation (5), we use these risk premiums to obtain estimates of dividend growth up to three-year horizons. We use dividend futures prices at available maturities, which vary by market, and use the term structure of government bond yields up to 30-year maturities in the discount rates for the first stage.[9,10]

Two additional inputs are used for the identification of the long end of the equity term structures: equity index levels and long-horizon survey-based estimates of nominal GDP growth. The terminal values of $\bar{y}_t$, $\bar{\theta}_t$, and $\bar{g}_t$ in the second stage are represented through forward rates. As described below, these are readily available from the Nelson-Siegel specification and are therefore consistent with the first stage of the model. For $\bar{g}_t$, we assume that long-run nominal dividend growth coincides with the expected nominal GDP growth. This assumption relies on the labour share of the total output being stable over the long term.[11]

Data

We use futures data from Bloomberg as our main data source for the euro area, Japanese, UK and US markets, which we collectively refer to as the "G4" markets.[12] To create a full sample of prices, we need to combine data on dividend futures and dividend swaps. In Appendix B, we outline how we construct daily futures prices covering the period from January 2003 to June 2021. The maturities of the futures contracts vary over time, in the same way that a bond's maturity rolls off after being issued. The estimation methods we use require dividend futures with constant maturities, which we construct by interpolating between fixed maturities using splines.

We use equity index options data from OptionMetrics. More details on the options data and construction of equity risk premium estimates across horizons are provided in Appendix C. For yields, we source zero-coupon nominal spot yields and forwards from ICE Indices (formerly BofA Fixed

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[7] Details are provided in Appendix C. We use the same approach for modelling the equity risk premium in NBIM (2021), where we show that the approach is successfully able to explain a large proportion of variation in equity returns. We also find that our estimates are able to forecast equity market returns, extending the predictive regressions reported in Martin (2017) to include data available since the original study, and also across the other G4 equity markets.

[8] We use an estimate of the equity risk premium – the expected excess return on the entire equity market – as a proxy for the dividend risk premium. While these two quantities are theoretically distinct, it is reasonable to assume they are closely related in practice. Goncalves (2019) derives the conditions under which the dividend risk premium coincides with the equity risk premium. Knox and Vissing-Jorgensen (2021) assume that the expected return on a dividend strip is proportional to the expected return on the market.

[9] For dividend futures, we use constant-maturity futures from the one-year maturity onwards and exclude the two longest maturities to ensure that we use the more liquid segment of the market.

[10] To the extent that the yield curves used to discount cash flows are pushed down by convenience yields, our risk premium estimates will include this effect, and will be higher compared to an estimation approach that uses (unobserved) risk-free discount rates free of convenience yields.

[11] While the recent literature documents a downward trend in the labour share in recent decades, indicating non-stationarity, long-sample evidence suggests that the labour share tends to move in long cycles, e.g. Charpe, Bridji, and McAdam (2019).

[12] Dividend derivatives exist for indices such as the Hang Seng, SMI and country indices within the euro area. These markets are either small or less liquid than the G4, however.

Income Indices). The data are available at a daily frequency and at three-month maturity steps between three months and 30 years. We source daily equity price index levels from Bloomberg and survey-based estimates of nominal GDP growth at the ten-year horizon from Consensus Economics. As the survey data are available at a quarterly frequency, we convert the quarterly data to a daily frequency by carrying the last available observation forwards. Finally, our model estimation requires realised dividends as an input, D_t, which we obtain as the difference between the daily total return and price return for each equity index, details of which are provided in Appendix D.

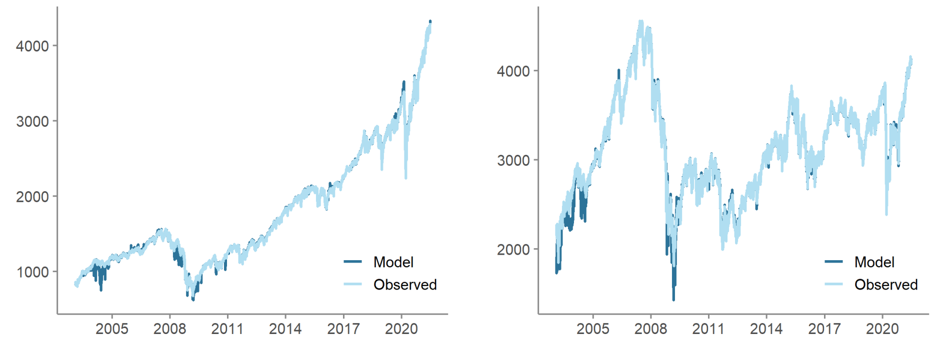
Model Estimation and Fit

To implement both stages of our model, we need to estimate eight parameters in total. One of the well-known advantages of the Nelson-Siegel specification is that the parameters have an intuitive interpretation. The first two parameters determine the long-run level of the term structure and its slope respectively. For example, for the risk premium term structure, β_{0t}^{θ} represents the level and β_{1t}^{θ} represents the slope. The other two parameters, β_{2t}^{θ} and τ_t^{θ}, jointly determine the shape and the location of the term structure hump. We exploit this parameter structure to implement the assumption about long-run dividend growth. Specifically, we set β_{0t}^{g} equal to the survey-based estimate of long-horizon nominal GDP growth. This modelling choice anchors the long end of the term structure of dividend growth, and together with the equity index levels determines the long end of the risk premium term structure.

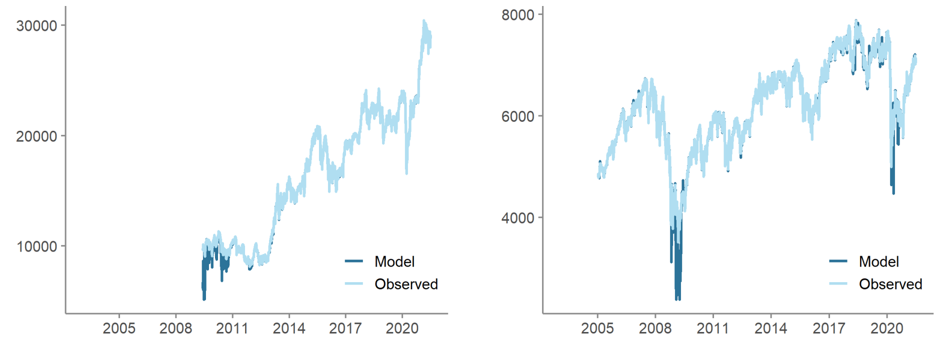
To estimate the remaining seven parameters determining $g_t^{(n)}$ and $\theta_t^{(n)}$, we minimise the sum of squared pricing errors between the model-implied and observed variables. Our optimisation balances pricing errors for the stock index, futures prices, risk premiums and dividend growth inputs. In penalising pricing errors, we account for higher liquidity and trading activity in dividend futures with shorter maturities (for the first three years) by giving them a higher weight relative to longer-maturity dividend futures.

Figure 1 shows modelled equity index prices alongside observed equity indices across all markets. We are able to closely match the variation in these prices, though there tends to be some deterioration in fit earlier in the sample period and during the 2008-2009 financial crisis.

Figure 1: Model fit for G4 equity index prices



(a) United States *(b) Euro area*



(c) Japan *(d) United Kingdom*

In addition to matching the pricing of equity indices, we are also able to match dividend futures prices. Focusing on the short-maturity futures that have a relatively higher weight in the estimation, Table 2 reports the correlations between modelled and observed price changes of dividend futures at a daily (Panel A) and weekly (Panel B) frequency.[13]

Given that we estimate the model each day without using any information from past observations, aiming for high correlations between modelled and observed price *changes* should be viewed as a challenging test of the model. The modelled prices of dividend futures are closely aligned with the observed prices, where the correlations at a daily frequency are high and mostly exceed 0.80. Microstructure effects and measurement errors are the likely cause of lower correlations at a daily frequency. To the extent these effects are transitory, the correlations of weekly price changes should be closer to unity across all markets. Panel B of Table 2 shows that this is indeed the case. A tight fit to observed equity index and dividend futures prices, together with the high correlation between the model-implied and observed prices, implies that the model provides an accurate and timely decomposition of equity returns.

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[13] We penalise the pricing errors for the index similarly to pricing errors for the other model inputs, implying that the close fit of the index price is not guaranteed. The ability to match the index and other prices is partly achieved through adjustment in the long-term risk premium estimate, β^{θ}_{0t}.

Table 2: Correlation of modelled and observed price changes of dividend futures

Maturity (years)	United States	Euro area	Japan	United Kingdom
	Panel A. Daily changes			
1	0.90	0.86	0.40	0.64
2	0.87	0.91	0.73	0.88
3	0.80	0.87	0.78	0.79
	Panel B. Weekly changes			
1	0.97	0.93	0.79	0.87
2	0.97	0.97	0.94	0.97
3	0.94	0.95	0.95	0.93

Note: The table reports correlations between modelled and observed daily (Panel A) and weekly (Panel B) dividend futures price changes. Weekly correlations are estimated using overlapping daily data. The sample period varies by market – from Jan 2003 for the US and euro area, Jun 2009 for Japan and Jan 2005 for the UK – and ends in Jun 2021.

5. Term Structures of Expected Dividend Growth and Risk Premiums

In this section, we describe the dynamics of the estimated term structures of expected dividend growth and risk premiums. We then use our present-value model to decompose the equity indices into their sources of value at different horizons, and estimate the duration of G4 equity markets.

Term Structure Estimates

Figure 2 shows dividend growth estimates for one-, five- and ten-year maturities across the G4 markets. The dividend growth estimates display a high degree of cyclicality, strongly co-moving with the economic cycle.[14] This cyclicality is particularly apparent in episodes where expected dividend growth was revised significantly downwards, such as during the 2008 financial crisis and Covid-19 pandemic outbreak in 2020. We also observe greater cyclicality at shorter horizons, where 12-month dividend growth fell to below -25 percent for the US and below -30 percent in the other markets during these episodes. Estimates of 10-year dividend growth rates are more stable over time than their short-term counterparts.

Figure 3 shows our estimates of risk premiums at different horizons for G4 markets. The estimates vary counter-cyclically, increasing sharply during the financial crisis and pandemic episodes, and co-move strongly across markets particularly during market downturns. In line with evidence in Binsbergen, Brandt, and Koijen (2012), the shorter-term estimates display greater variation than the longer-horizon estimates. For example, during the financial crisis, the 12-month estimates for the US, euro area and UK reached around 16 percent, compared to around 5 percent for the 120-month estimates.

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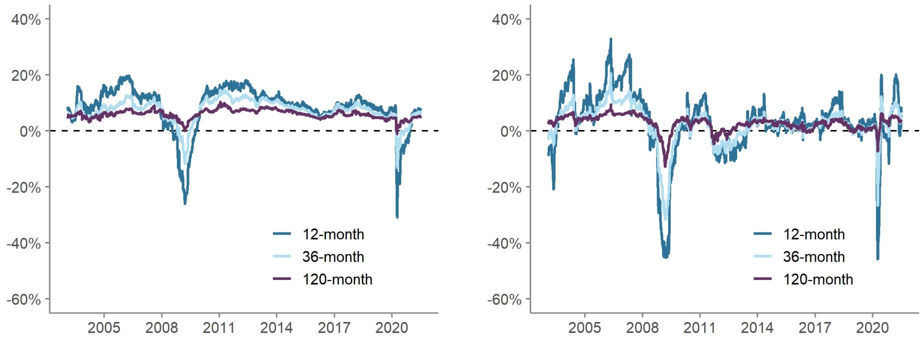
[14] For example, the correlations between one-year expected dividend growth and one-year forecasts of GDP growth from Consensus Economics range from 0.60 to 0.76 across the G4 markets.

Figure 2: Estimated expected dividend growth for G4 equity markets (annualised)

(a) United States (b) Euro area



(c) Japan (d) United Kingdom

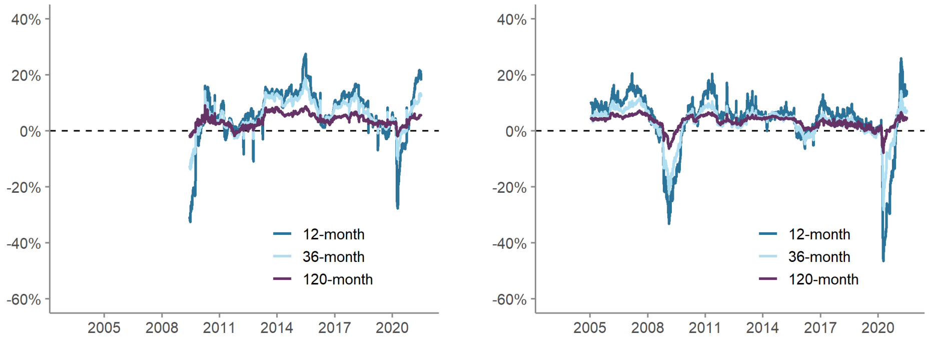
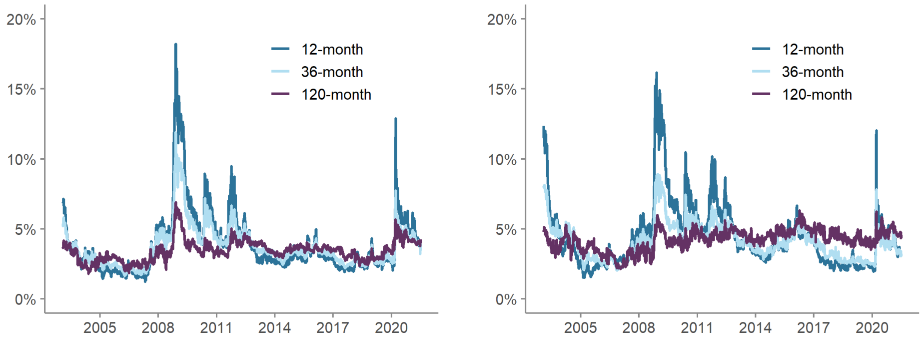


Figure 3: Estimated risk premiums for G4 equity markets (annualised)

(a) United States (b) Euro area



(c) Japan (d) United Kingdom

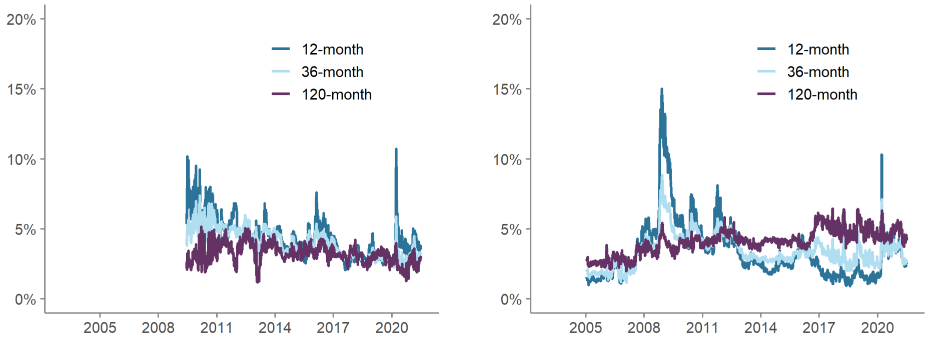
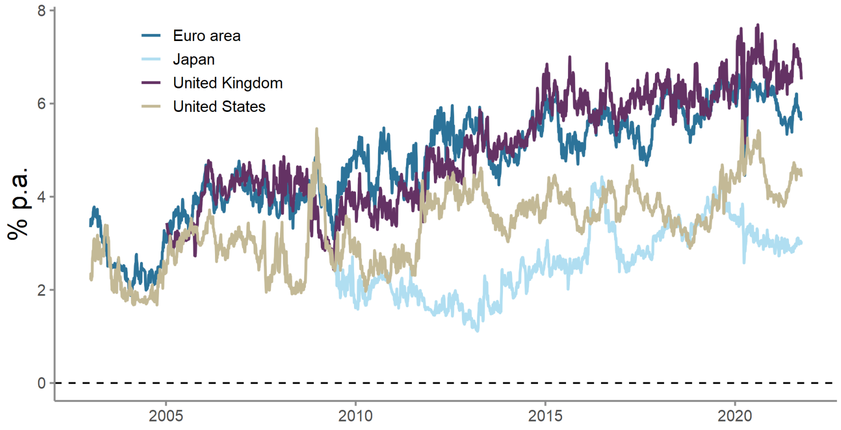


Figure 4: Parameter estimates of β_{0t}^{θ}, the level factor of the risk premium term structure



Note: The chart shows the estimates of the parameter β_{0t}^{θ} in the Nelson-Siegel specification, which represents the level effect of the term structure of the dividend risk premium, see Appendix E for more details.

As described in the previous section, our modelling approach allows us to estimate full term structures of dividend growth and risk premiums. In particular, using our methodology, we can obtain risk premium estimates at the long end of the term structure. Through use of the present-value identity, these risk premiums are consistent with dividend futures prices, shorter-term risk premium estimates and long-term growth. Figure 4 shows the evolution of these estimates, captured by the level component of the term structure in our estimation approach. In particular for the US, euro area and UK, the estimates display an upward trend over most of the sample period.

The upward trend does not necessarily mean that the expected equity returns have also trended upwards over the same period. There are two reasons for this. First, long-horizon expected equity returns are estimated using the risk premiums across the entire term structure. As a result, the estimates presented in Figure 4 need to be considered alongside shorter term risk premium estimates. Second, the expected return on a risk-free government bond is an important component of the expected equity return. Yields on government bonds across G4 markets have been declining steadily over most of our sample period. Taken together, expected equity returns have trended downwards over the last decade. We plan to provide an in-depth discussion of expected equity returns in future work.

Decomposing Index Value by Horizon

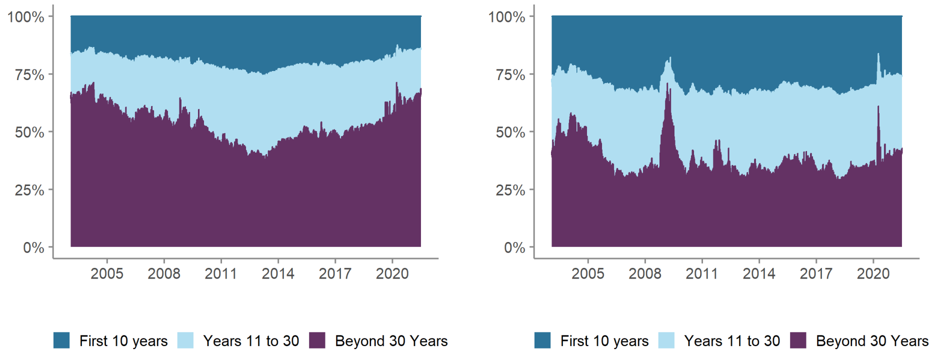
While there is significant variation in the dividend growth and risk premium estimates, our methodology also allows us to understand the implications of their variation for the overall stock index. Using the present-value model, we can estimate the amount each component of the term structure contributes to the total value of the index. As shown in equation (6), the stock market price can be expressed as the sum of all index dividend prices. The contribution of each index dividend to the value of the equity index is given by:

$$w_t^{(n)} = \frac{P_t^{(n)}}{S_t}, \tag{8}$$

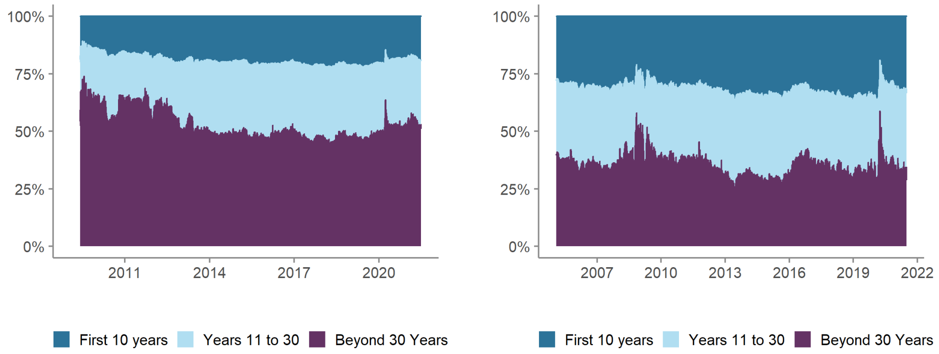
which describes how the value of the market is distributed across horizons. Based on our two-stage model, each cash flow at horizons up to 30 years is assigned an individual weight, while the remaining cash flows beyond this point are assigned a single weight determined by the terminal-value component in the present-value equation. Figure 5 decomposes each market over time, showing the distribution of weights by horizon. The charts split each equity index into three present-value components: 1) near-term dividends paid out over the next ten years, 2) dividends paid out from year 11 to year 30, and 3) all remaining dividends beyond 30 years.

Figure 5: Decomposing the value of G4 equity indices

(a) United States *(b) Euro area*



(c) Japan *(d) United Kingdom*



Note: The figure shows the split of the value of G4 equity indices into present value of dividends in the first ten years, present value of dividends in years 11 to 30, and present value of all the remaining dividends. Start of the sample period varies by market: January 2003 for the euro area and the US, July 2004 for Japan, and January 2005 for the UK.

The chart shows that the majority of the value occurs beyond ten years for all markets. Indeed, the component capturing cash flows beyond 30 years captures over 50 percent of the value on average in the US and Japan, and over 30 percent for the euro area and UK. The decompositions put the term structure estimates shown earlier into context. Despite their significant variation over time, the estimates for horizons up to ten years constitute a relatively small proportion of the total index value, and contribute a smaller amount to variation in the value of the stock index compared to the longer-horizon components.

Near-term changes in expected equity cash flows, for example at one- or two-year horizons, often tend to be the focus of equity market participants. Our results indicate that the importance of short-horizon expectations for equity price variation depends on the extent to which they are persistent enough to also be reflected in longer-horizon expectations.

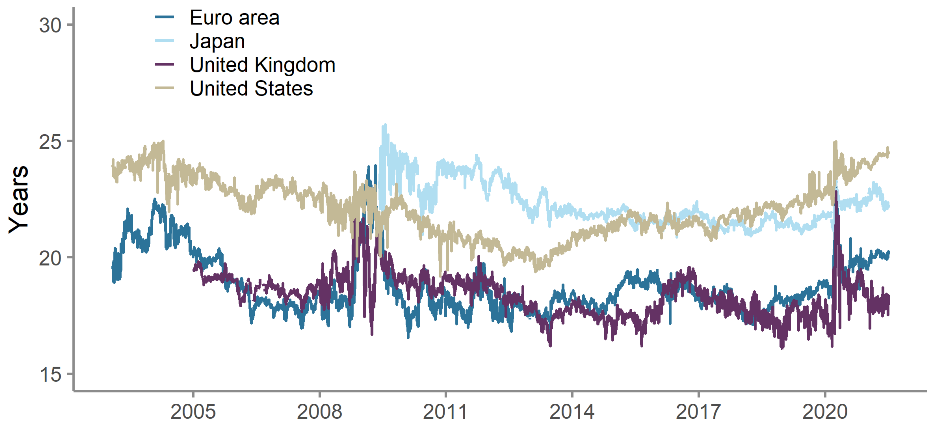
Equity Duration

The distributions of the index values across horizons can also be summarised by measures of the equity market duration. Duration is a key metric for describing the horizon of an asset's cash flows, which is more commonly associated with fixed income securities. Our modelling approach allows us to estimate the duration of the equity market, defined as:

$$Dur_t = \sum_{n=1}^{\infty} w_t^{(n)} \times n. \tag{9}$$

As highlighted in Binsbergen (2021), it is important to measure the duration of equities when comparing equity performance to other assets, in particular fixed income assets. In order to conduct a fair performance comparison, equities should be compared to assets with equally long duration, rather than assets such as short-term Treasury bills. Binsbergen (2021) provides empirical evidence that average realised equity returns are not higher than duration-matched bond returns. Figure 6 shows our estimates of duration for the G4 markets.

Figure 6: Equity duration in G4 markets



Note: The chart shows estimates of equity duration in G4 markets. The estimates are obtained using the formula in equation (9). Monthly data. Sample period ends in June 2021. Start of the sample period varies by market and is determined by data availability.

Our estimates indicate that equity duration varies between 16 and 26 years over time and across markets, where the US and Japan have consistently higher duration compared to the euro area and the UK. The dispersion in duration remains high in the latest part of the sample, despite the fact that interest rates across G4 markets have converged towards zero around this period. Unlike bond duration, where the sole driver is the level of interest rates, equity duration is also determined by risk premiums and dividend growth. Higher long-term risk premiums will reduce equity duration, all else equal, while higher long-term dividend growth expectations will increase duration.

The estimates in Figure 4 indicate that the long end of the risk premium term structure has increased in the period following the 2008-2009 financial crisis, while long-horizon dividend growth expectations have trended downwards. These forces apply downward pressure on duration, however our measure for the US has increased over this period. This implies that declining interest rates have offset these effects and pushed up duration in the US. For the other markets, duration measures have been relatively stable, where declining interest rates have offset changes in risk premiums and growth expectations.

6. Summary

We estimate term structures of expected dividend growth and risk premiums for the US, euro area, Japanese and UK markets. We use a present-value modelling approach that combines dividend futures prices, stock index prices, option prices and survey data that facilitate estimation of term structures from short to long maturities. Our model is able to closely fit price data, where the term structures can explain most of the variation in stock index prices. We show that expected dividend growth and risk premiums vary significantly over time, particularly for shorter horizons and during market downturns. Our approach allows us to decompose index value by horizon, and we find that the majority of the value occurs beyond ten years across G4 markets. We are also able to estimate equity market duration, where our estimates range from 15 to 25 years across the G4 markets.

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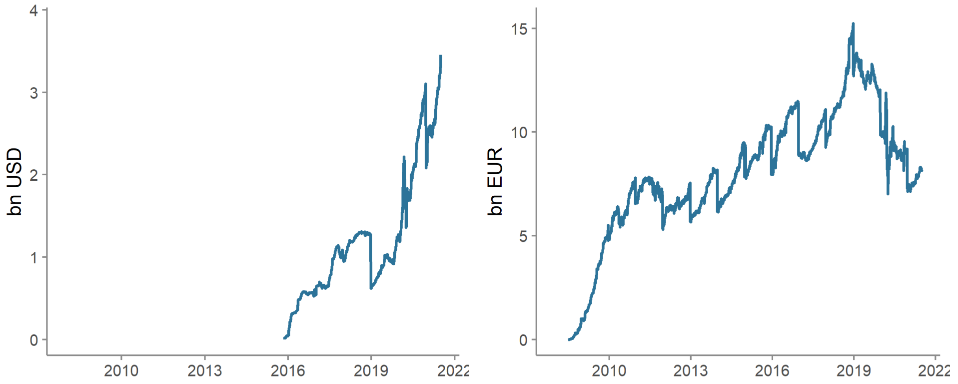
Appendix A: Liquidity and informativeness of dividend futures

Figure 7 shows the size of G4 dividend futures markets. EURO STOXX 50 dividend futures are by far the largest market with around 10 billion euros of notional outstanding. Note that these numbers only include exchange-traded instruments and exclude the OTC market. In the earlier part of our sample period, most of trading was conducted OTC.

To gauge liquidity across dividend futures contracts of different maturities, Table 3 shows open interest for G4 dividend futures with maturities covering one to five years. Euro area futures, which have the longest trading history, are by far the most liquid of the four markets, both in aggregate and across maturities. Open interest in the other three markets is more comparable. Across all four markets, open interest declines once we move beyond maturities of two to three years.

Figure 7: Size of G4 dividend futures markets

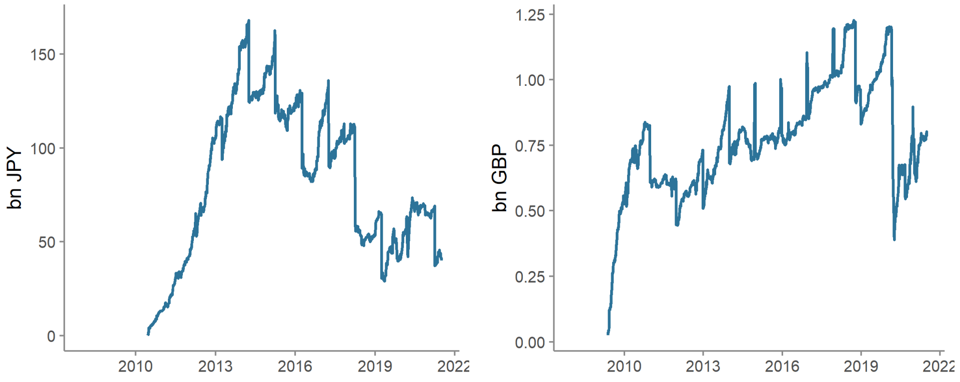


(a) United States

(b) Euro area

(c) Japan

(d) United Kingdom



Note: Panels show the notional outstanding in the dividend futures market for the euro area, Japan, the UK and the US. All data are in billions of local currency. Sample period ends in June 2021. Start of the sample period varies by market. Data are sourced from Bloomberg.

Table 3: Open interest (million US dollars) for G4 dividend futures at one- to five-year maturities

Maturity (years)	United States	Euro area	Japan	United Kingdom
1	840	2,584	310	265
2	584	2,377	244	263
3	465	1,434	50	187
4	124	1,225	16	124
5	55	639	1	13

Note: Data are sourced from Bloomberg, as of 31 December 2020.

Appendix B: Dividend Futures and Swaps

For all G4 equity markets, we obtain prices of dividend futures and swaps from the following three sources:

- *Daily closing prices of dividend futures from Bloomberg.* We use dividend futures for the G4 markets written on the indices described in Table 1. The starting dates vary by market: June 2008 for the euro area, June 2010 for Japan, May 2009 for the UK, and November 2015 for the US.
- *Daily dividend swap prices from BNP Paribas.* The sample period is January 2003 to May 2013 for all four markets.
- *Daily dividend swap prices from Goldman Sachs.* Available for the UK and the US. The sample period is January 2008 to April 2020 for both markets.

Combining the three sources allows us to construct a dataset that covers the period starting in January 2003 at a daily frequency. For historical data, we prioritise data sources as follows: 1) swaps from Goldman Sachs, 2) swaps from BNP Paribas, 3) futures from Bloomberg. We prefer swaps over futures historically because most of the trading took place in the OTC swap market when we go back in time. Beyond that, the ordering is based on our own pricing quality checks. Our dataset therefore contains two types of dividend contracts: dividend futures and dividend swaps. Throughout the note, use "dividend futures" to refer to the combined sample of futures and swaps.

Appendix C: Extracting risk premiums from options

We consider options with expiration dates ranging between one month and three years. The availability of option data varies across markets. Estimates for the US start in January 1996, January 2002 for the euro area , June 2009 for Japan and in January 2005 for the UK. To obtain constant-maturity estimates of risk premiums, we interpolate between observed maturities.

To develop an option-based measure of the equity risk premium, Martin (2017) relies on an inequality that places a lower bound on the equity risk premium. The lower bound is a function of the risk-neutral variance of the market return and is extracted from equity index options. We use the lower bound, labelled SVIX, as a proxy for the equity risk premium.

We source the option data from OptionMetrics, which provides security- and index-level data covering the US, European, and Asian markets. While OptionMetrics is a very rich dataset, there are several issues that require careful treatment in order to construct robust and stable estimates. First, the dataset contains many illiquid options with stale prices. This introduces non-convexity in prices and reduces the accuracy of our estimates. Second, the number of strikes available at each maturity can fluctuate wildly (i.e. different degrees of discretisation in strikes), making our estimates unstable. To account for these issues, we apply several filters to the data before calculating our estimates. In particular, we remove all options with:

- Missing deltas and implied volatility;
- Special settlements;
- Best bids less than zero;
- No last trade date (where available);
- Less than seven days to maturity;
- All maturities with fewer than seven out-of-the-money strikes.

Another consideration when estimating SVIX is the availability of target maturities, i.e. maturities for which we want an estimate of the equity risk premium. We choose to estimate the equity risk premium in one-month intervals up to one year, and three-month intervals up to three years. However, option maturities at such intervals are not always available for each date. We address this issue by estimating SVIX for all maturities and linearly interpolating between the two closest maturities.

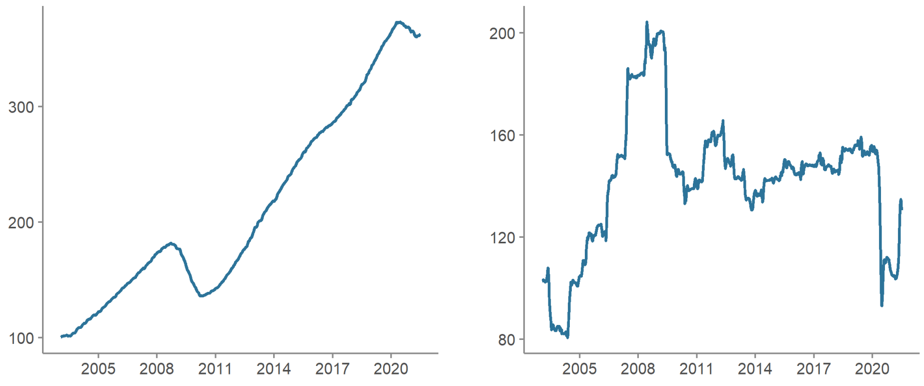
Appendix D: Realised Dividends

We estimate realised dividends D_t as the difference between daily total and price returns cumulated over one year:

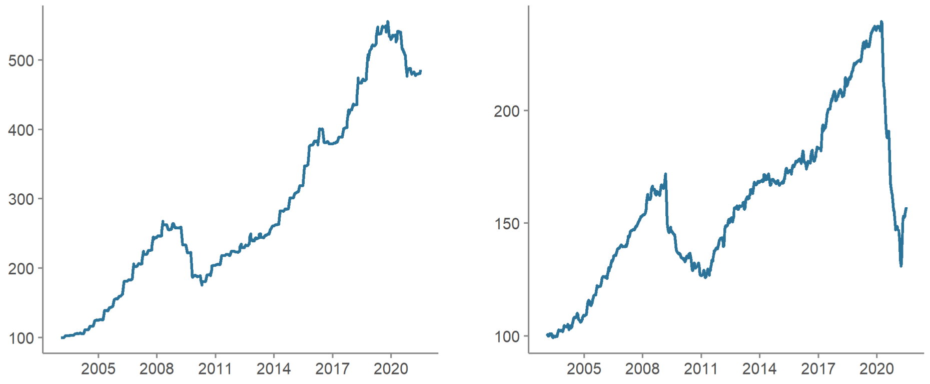
$$D_t = \sum_{j=t-1Y}^{t} PRI_{j-1} \left(\frac{TRI_j}{TRI_{j-1}} - \frac{PRI_j}{PRI_{j-1}} \right), \tag{10}$$

where TRI_t and PRI_t refer to the total return and price return indices, respectively. Figure 8 shows our estimates of current index dividends for all G4 markets.

Figure 8: Realised index dividends across G4 equity markets



(a) United States *(b) Euro area*



(c) Japan *(d) United Kingdom*

Note: The panels show daily rolling sums of index dividends paid out over the last 12 months for the US, Japan, the euro area and the UK. Realised index dividends are extracted as the difference between the total return and price return indices using the formula given by equation (10)*. We use realised index dividends over the last 12 months to approximate the current index dividend D_t. The sample period is January 2003 to June 2021.*

Corporate payout policies differ substantially across the G4, and the degree of dividend smoothing is perhaps the most visible difference across markets. Companies in the euro area tend to pay dividends once a year, usually in May or June. US companies, on the other hand, tend to pay dividends quarterly. The smoothness of US dividends is also related to share buybacks, which is another way of returning cash to shareholders. This payout policy is more common in the US than in the euro area and offers companies a more flexible way of distributing cash to shareholders, thus further smoothing dividend payouts. The payout policies of Japanese and UK companies are somewhere in between these two extremes.

Appendix E: Nelson-Siegel model of term structures

We express expected per-period dividend growth for maturity n denoted by $g_t^{(n)}$ as follows:

$$g_t^{(n)} = \beta_0^g + (\beta_{1t}^g + \beta_{2t}^g)\left[1 - \text{exp}\left(-n/\tau_t^g\right)\right] / \left(n/\tau_t^g\right) - \beta_{2t}^g \,\text{exp}\left(-n/\tau_t^g\right). \qquad (11)$$

Hence, $g_t^{(n)}$ for any maturity is a function of four parameters which are estimated for each period. We use an identical specification for the term structure of risk premium $\theta_t^{(n)}$:

$$\theta_t^{(n)} = \beta_{0t}^\theta + \left(\beta_{1t}^\theta + \beta_{2t}^\theta\right)\left[1 - \text{exp}\left(-n/\tau_t^\theta\right)\right] / \left(n/\tau_t^\theta\right) - \beta_{2t}^\theta \,\text{exp}\left(-n/\tau_t^\theta\right). \qquad (12)$$

The specification given by equations (11) and (12) refers to the "spot" growth rates, i.e. the annualised average growth rate between times t and $t+n$. The specification can be easily converted to "forward" growth rates using the Nelson-Siegel model specification.