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CORONAVIRUS: IMPACT ON STOCK PRICES AND GROWTH EXPECTATIONS

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ABSTRACT

We use data from the aggregate stock market and dividend futures to quantify how investors' expectations about economic growth evolve across horizons in response to the coronavirus outbreak and subsequent policy responses until June 2020. Dividend futures, which are claims to dividends on the aggregate stock market in a particular year, can be used to directly compute a lower bound on growth expectations across maturities or to estimate expected growth using a forecasting model. We show how the actual forecast and the bound evolve over time. As of June 8, our forecast of annual growth in dividends is down 9% in the US and 14% in the EU compared to January 1, and our forecast of GDP growth is down by 2.0% in the US and 3.1% in the EU. The lower bound on the change in expected dividends is -18% in the US and -25% in the EU at the 2-year horizon. News about fiscal stimulus around March 24 boosts the stock market and long-term growth but did little to increase short-term growth expectations. Expected dividend growth has improved since April 1 in both the US and the EU. We conclude by developing and estimating a simple model of the crisis to understand the joint dynamics of short-term dividend futures, stock markets, and bond markets.

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1 Introduction

The outbreak of the new coronavirus has caused a pandemic of respiratory disease (COVID-19) for which vaccines and targeted therapeutics for treatment are unavailable as of May 2020 (Wang et al. (2020)). The outbreak has caused major concerns about public health around the world. At the same time, there are growing concerns about the economic consequences as households are required to stay home to slow the spread of the virus. The impact that "pausing" the economy may have on supply chains and the financial stability of firms, the financial sector, and households is largely unknown. As a result, policymakers, businesses, and market participants try to estimate growth expectations for the years to come and assess the shape of the recovery.

As the current situation is unprecedented, and evolving rapidly, models that use macro-economic fundamentals to form expectations may miss some of the key forces and may be too slow to update given the frequency with which macro-economic data become available. It has long been recognized that asset prices may be particularly useful as they reflect investors' expectations about future payoffs. A natural starting point may be stock markets, bond markets (Harvey (1989)), and credit markets (Gilchrist and Zakrajsek (2012)). Indeed, much of the media commentary has evolved around these markets. In particular the movements in the stock market have received a lot of attention. In this paper, we provide a perspective on how to interpret movements in the stock market and what they tells us about growth expectations by combining it with asset pricing data from other markets.[1]

Equity markets in the US and the EU dropped by as much as 30%. This is an extraordinary amount. To interpret this decline, it is useful to recall that the value of the stock market, S_t, is equal to the discounted value of all future dividends

$$S_t = \sum_{n=1}^{\infty} \frac{\mathbb{E}_t\left[D_{t+n}\right]}{1+\mu_t^{(n)}}, \tag{1}$$

where $\mathbb{E}_t D_{t+n}$ is the expected dividend in n years from today, conditional on today's information, and $\mu_t^{(n)}$ the cumulative discount rate for that cash flow. If the stock market falls,

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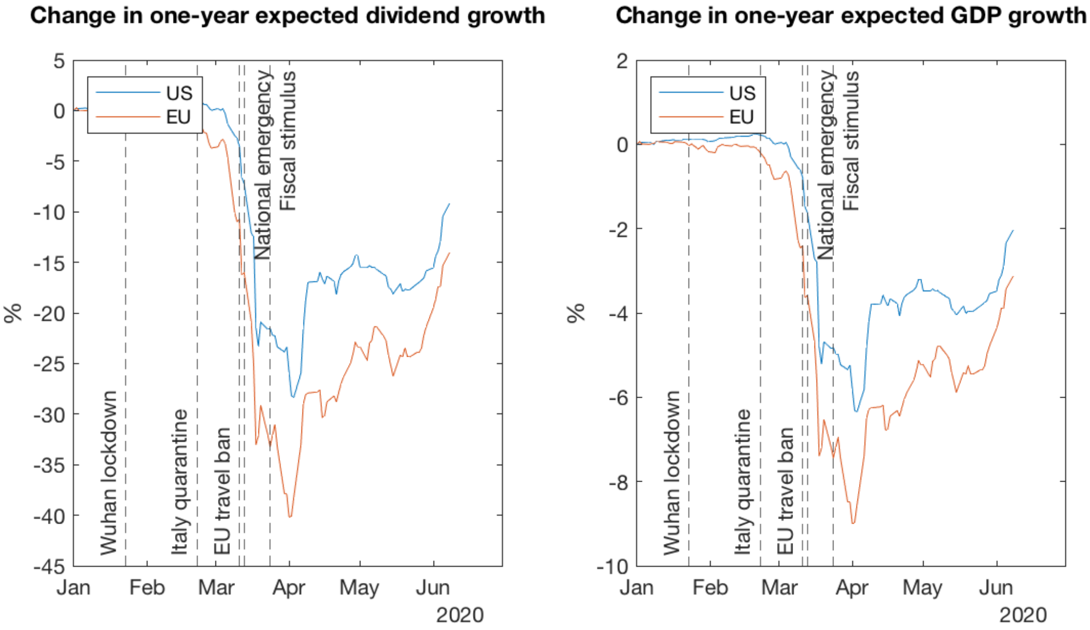
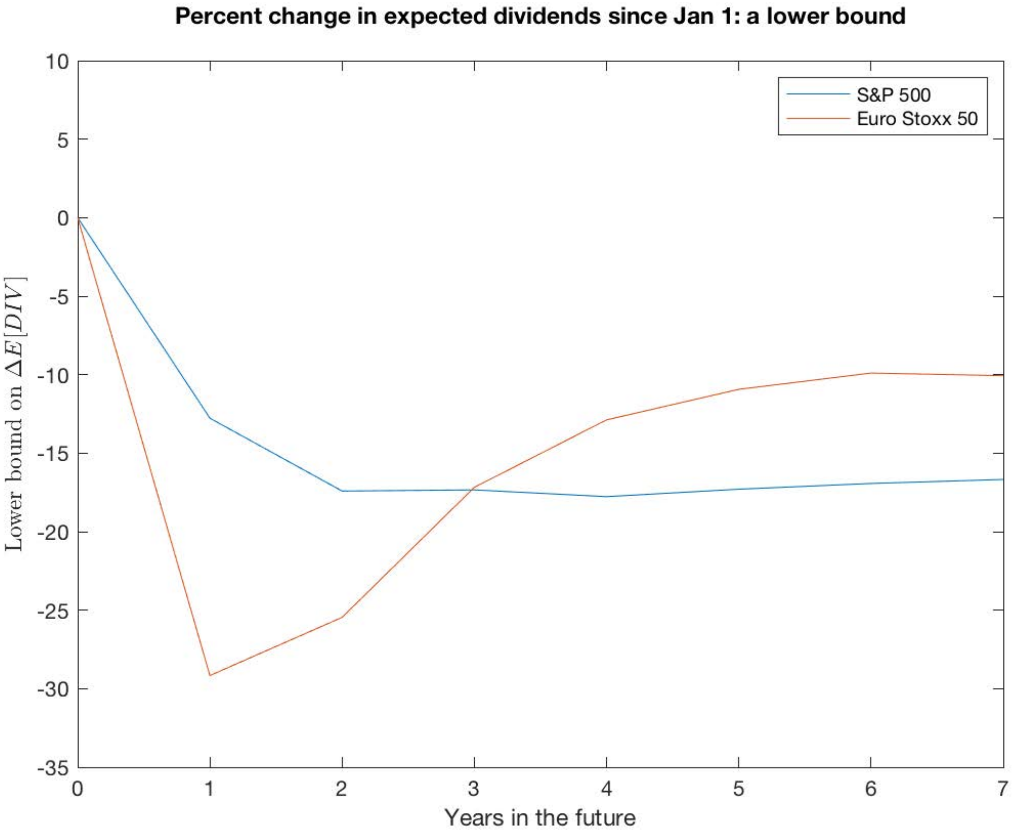
[1] Ramelli and Wagner (2020) look at the cross-section of stock price reactions to COVID-19 events to understand the factors that impacted investors' demand during the onset of the crisis.

Figure 1: Expected Dividend and GDP Growth from Dividend Futures



This figure shows the change in expected dividend and GDP growth relative to expected value at January 1, 2020. The figure shows expected growth in the US in blue and in the EU in red. Key events are indicated by the vertical dashed lines. The expected dividend growth is revised slowly in response to the outbreak, particularly in the US where it was revised down by less than 5% at March 11. By June 8, expected dividend growth is down by 9% in the US and 14% in the EU. Expected GDP growth over the next year is down by 2.0% in the US and 3.1% in the EU. We emphasize that these numbers are based on historical relations between growth and asset prices and come with uncertainty. Details of the estimation are in Section 5.2.

Figure 2: Lower bound on revisions in expected growth at different horizons



This figure shows a lower bound on revision in expected dividend growth at different horizons. The revisions are measured relative to expectations on January 1. The figure shows the bound for the S&P 500 in blue and the bound for Euro Stoxx 50 in red. The lower bound bottoms out between 1 and 2 years into the future, with expected dividends being revised down by as much as 18% in the US and 29% in the EU. The lower bound increases from years 1 to 7 in EU, which is consistent with investors expecting catch-up growth after the recession. We emphasize that the estimates represent lower bounds and that actual expected growth is likely higher.

then either expected future dividends fall or investors discount future dividends at a higher rate, that is, $\mu_t^{(n)}$ rises.

For the stock market to decline by 30% only due to revised growth expectations, the shock to future dividends needs to be large and highly persistent. It would for instance be inconsistent with a V-shaped recovery. To see this, we can sum the dividend prices over the first 10 years and find that this accounts for about 20% of the value of the stock market. This implies that if discount rates do not move and the economic impact on dividends lasts no more than 10 years, a 30% decline in the stock market would mean that firms pay no dividends in the next 10 years - seemingly a rather extreme scenario. It would correspond to an L-shaped recovery in which dividends permanently drop by 30%, with no catch-up growth.

However, focusing on fundamentals only is typically not the right way to interpret movements in the stock market. The seminal work by Shiller (1981) and Campbell and Shiller (1988) shows that most of the variation in the value of the stock market is due to changes in expected returns, $\mu_t^{(n)}$, not revisions in expected future growth rates. See COCHRANE (2011) for an excellent review. This insight brings good and bad news. The good news is that investors' expectations did not decline as dramatically as in the earlier calculation. The bad news, however, is that we learn little about growth expectations by taking cues from the stock market. Instead, we learn about investors' changes in discount rates that may be driven by shifts in risk aversion, sentiment, or uncertainty about long-run growth.

Our main point is that data from a related market, namely dividend futures, are useful to obtain estimates of growth expectations *by maturity*. Dividend futures are contracts that only pay the dividends of the aggregate stock market in a given year.[2] We can convert these prices to make each of the components of (1),

$$P_t^{(n)} = \frac{\mathbb{E}_t\left[D_{t+n}\right]}{1+\mu_t^{(n)}}, \tag{2}$$

directly observable.

We refer to $P_t^{(n)}$ as the price of the $n-$year dividend strip at time t. If we sum all dividend

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[2] See van Binsbergen et al. (2012), van Binsbergen et al. (2013), van Binsbergen and Koijen (2017), and Gormsen (2020) for earlier work on dividend strips and dividend futures.

strip prices, they add to the market, $S_t = \sum_{n=1}^{\infty} P_t^{(n)}$. There are two important reasons that data on dividend strip prices are informative. First, van Binsbergen et al. (2013) show that prices of dividend strips provide good forecasts of dividend growth and economic growth more broadly. Second, and particularly relevant during this period, dividend strips are differentiated by maturity, just like nominal, real, and corporate bonds. We use this feature of the data to provide an estimate of expected growth over the next year and to obtain a lower bound on the term structure of growth expectations by maturity.

Figure 1 shows the dynamics of expected dividend and GDP growth expectations in the US and in the EU until June 8. Growth expectations did not respond much to the Wuhan lockdown. Following the lockdown in Italy, growth expectations start to deteriorate. The travel restrictions on visitors to the US from the EU leads to a sharp deterioration of growth expectations. This is occurs once again following the declaration of the national emergency and the subsequent actions by the Federal Reserve on March 15. Following the US fiscal stimulus program, GDP growth has stabilized somewhat in the US but continued to deteriorate in the EU. By June 8, expected dividend growth over the next year is down by 9% for the S&P 500 index and 14% for the Euro Stoxx 50 index. The estimate of GDP growth over the next year is down by 2.0% in the US and 3.1% in the EU.[3]As a word of caution, we emphasize that these estimates are based on a forecasting model estimated using historical data. In these unprecedented times, there is a risk that the historical relation between growth and asset prices changes, meaning these estimates come with uncertainty.[4]Nevertheless, in discussing what asset markets may tell about investors' growth expectations, we argue that dividend futures should play a central role.

We also derive a lower bound on expected dividend growth by horizon, which can be computed directly using observed prices. The lower bound is forward looking and requires neither a forecasting model nor historical data, which makes it useful in our setting, and only relies on the assumption that expected excess returns have not decreased.

The lower bound is plotted in Figure 2. The figure displays the lower bound on the

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[3] The chief economist of Goldman Sachs, Jan Hatzius, revised his forecast for GDP growth in 2020 down to 0.4%, compared with a prior growth estimate of 1.2% on March 15.

[4] An additional reason for the changing link between dividend futures and future GDP growth is that governments and regulators may impose restrictions on firms' payout policies in return for financial support or to safeguard the financial system in case of banks and insurance companies.

change in expected dividends on the vertical axis and the horizon on the horizontal axis. As of June 8, the lowest value of the lower bound is 18% in the US and 29% in the EU, relative to January 1. There are signs of catch-up growth from year 1 to year 7 in the EU as the bound is substantially higher at longer horizons. We study how the bound evolves during the crisis in response to news and policy decisions, which provides a narrative as to how investors interpreted these events.

We compare the lower bound observed during the coronavirus crisis to the lower bound observed during the November 2008 of the global financial crisis (GFC). On March 23 2020, the day with the lowest price of S&P 500 during the coronavirus crisis, the lower bound on dividend growth is as low, or lower, than what we observed during the financial crisis. The lower bound does, however, show stronger signs of catch-up growth than during the GFC. The comparison to the financial crisis is useful as we show that the lower bound was quite tight during the previous recession. The lower bound on the change in growth rates was almost 30% at the 2-year horizon, and dividends indeed fell short of the pre-crisis trend by almost 30% after two years. These results suggest that even in a stressed financial system, dividend futures are closely related to future fundamentals and therefore contain useful information.[5]

We also use the dividend futures to better understand the overall movement in the stock market. During the onset of the crisis, the stock market drops substantially more than the 1- to 7-year dividend strips. This finding implies that the value of distant-future dividends – dividends paid out more than 7 years from today – must have dropped by more than the value of the near-future dividends. As we find it unlikely that long-run dividends, in levels, are hit harder than near-term dividends, the drop must come from discount rates.[6] Hence, prices on the market and the futures jointly suggest that discount rates initially increased substantially on long-maturity claims such as the market portfolio.[7] We formalize this analysis at the end of the paper.

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[5] A related concern is that dividend futures market may not be as liquid as other equity markets. However, van Binsbergen et al. (2013) show that dividend futures forecast economic growth better than other price-based forecasts such as bond yields.

[6] We refer to Eichenbaum et al. (2020) for a macroeconomic model of epidemics that is consistent with this assumption.

[7] The importance of long-horizon discount rate variation to understand movements in the aggregate stock market is consistent with (Gormsen, 2020).

As of June 8, the expected return on the market has returned to the pre-crisis level. On June 8, the S&P 500 trades at \$3232, which is \$64 lower than the average price between January 1 and February 19. This drop can largely be explained by the first 7 years of dividends, as they are down by a total of \$72. As such, the distant-future dividends, the dividends beyond year 7, must have approximately the same value as before the crisis. If expected long-run dividends are the same as before the crisis, expected returns on the long-run dividends must therefore also be the same as before the crisis. However, interest rates have dropped substantially, which means the expected return in excess of the interest rates is higher than before the crisis.

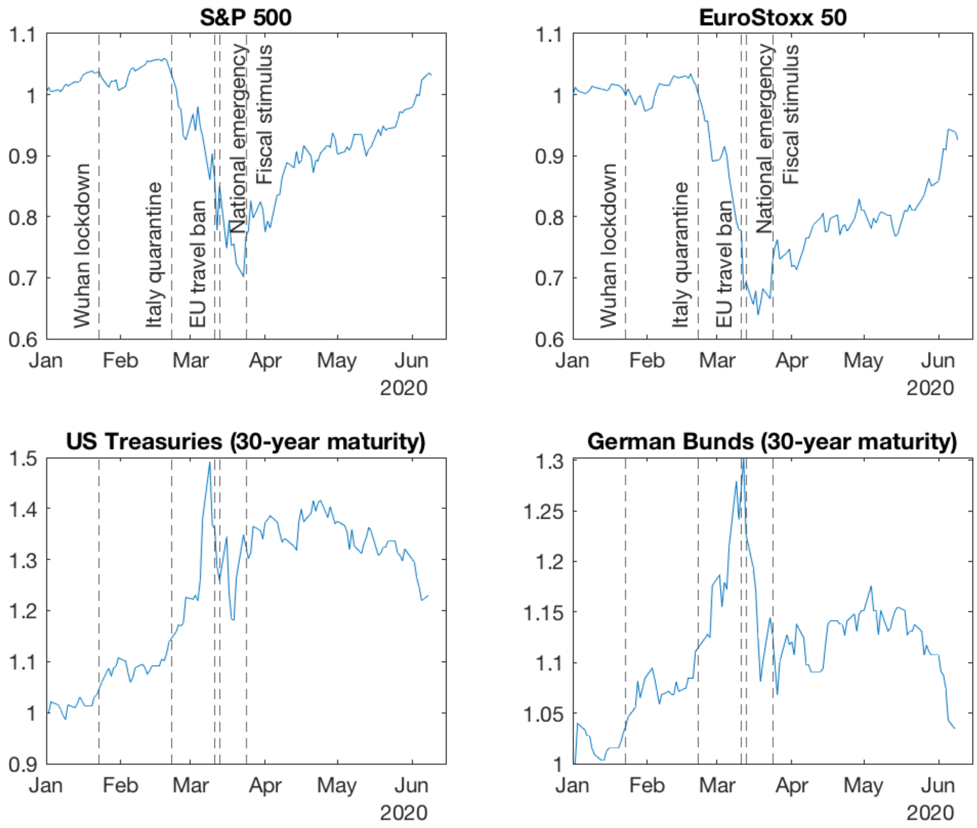
Our results have implications for asset pricing theories. It is well known that it is oftentimes difficult to identify the economic shocks that caused asset prices to move (Cutler et al. (1989)). The unique feature of the ongoing events is that the nature of the shock is clear, and we have a prior regarding the temporal structure. We discuss this in more detail in Section 9. We conclude by developing a simple asset pricing model of pandemics that we can easily calibrate and estimate in Section 10. The model allows us to understand the joint dynamics of short-term dividend prices, the aggregate stock market, and bond prices during the crisis.

2 The Stock and Bond Market Response to COVID-19

Figure 3 shows the cumulative return on the stock markets in the US and in the EU in the top panels. We use the S&P500 index as the representative stock index in the US and the Euro Stoxx 50 index in the EU. The bottom panels show the cumulative return on 30-year nominal bonds in the US and in Germany. Neither of the stock markets responded strongly to the outbreak in China or the lockdown of Wuhan, China, on January 23. However, once it is apparent that the outbreak spread to Italy, South Korea, and Iran, around February 20, stock markets declined sharply.

In response to the US' decision on March 12 to severely restrict travel from the EU, with the exception of the UK, and decisions by governments in the EU to impose lockdowns to various degrees, stock markets around the world declined by 10% or more. By March 18, stock markets have dropped more than 30% from their peak. On March 24, S&P 500 rallies

Figure 3: The response of the stock and nominal bond markets in the US and EU



This figure shows the cumulative return on the S&P 500, the Euro Stoxx 50 index, 30-year US Treasuries, and 30-year German bunds. We depict using dashed vertical lines the following five events: The lockdown of Wuhan, China on January 23, the announcement of the quarantine in Italy on February 22, the announcement by the US government that it would ban travel from the EU on March 11, the declaration of national emergency in the US on March 13, and the news that congress is close to passing a stimulus bill on March 24.

almost 10% following news of fiscal stimuli.

In search of safety, investors' demand for long-term government bonds issued by the US and Germany increased. Over the same period, the yield on 30-year US Treasuries decreases by almost a percentage point, driving prices of 30-year bonds up by approximately 30%. We see a similar rally in German Bunds, which are the safe assets in the Euro area.

Stock returns are often measured in excess of the return on bonds. When measured in excess of 30-year bonds, the aggregate stock market falls by almost 60% at the bottom. This is a lower excess return than observed in any calendar month in modern US history. A central question for policymakers and market participants is how to read this decline in the stock market. That is, what does the decline tell us about the expected trajectory of future growth or changes in expected excess returns. In the remainder of this paper, we show that we can make progress on this question by using data on dividend futures and the stock market jointly.

3 The Temporal Nature of COVID-19 and Past Pandemics

To interpret the evolution of asset prices, it is useful to place the ongoing pandemic into historical context. The Centers for Disease and Control and Prevention (CDC) provides an overview of past pandemics.[8] The key takeaway is that pandemics tend to be relatively short-lived. For instance, the H1N1 virus spread in 1918 and 1919, the H2N2 virus in 1957 and 1958, the H3N2 virus in 1968, and the H1N1pdm09 virus in 2009. While the pandemic may spread more easily in today's interconnected world, the expectation is that a vaccine can be available within 2 years. So while the economic contraction may be very sharp, and potentially have long-lasting effects due to defaults of households, firms, parts of the financial sector, and even governments, we believe at the time of writing that it is reasonable to assume that the economic consequences are most severe in the next one or two years. Indeed, this reasoning has prompted policy proposals to flatten not only the pandemic curve, but also

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[8] https://www.cdc.gov/flu/pandemic-resources/basics/past-pandemics.html.

the recession curve (Gourinchas (2020)). We will interpret the dynamics of equity and bond markets through this lens.

4 The Response of Dividend Futures to COVID-19

To better understand the expected impact of COVID-19 on the economy over the next few years, we turn to the term structure of dividend prices. The equity term structure are prices of claims to the dividends of all firms in an index in a given year. To interpret the dividend strip price, we can write (2) as

$$P_t^{(n)} = D_t \frac{G_t^{(n)}}{1 + \mu_t^{(n)}},$$

where $G_t^{(n)} = \mathbb{E}_t\left[\frac{D_{t+n}}{D_t}\right]$ is the expected growth rate between years t and $t{+}n$. In practice, we do not directly observe the dividend strip price, but instead observe the dividend futures price, which we denote by $F_t^{(n)}$. The two prices are linked by the no-arbitrage relationship $F_t^{(n)} = P_t^{(n)}(1 + y_t^{(n)})$, which implies

$$F_t^{(n)} = D_t \frac{G_t^{(n)}}{1 + \theta_t^{(n)}},$$

where $y_t^{(n)}$ is the cumulative $n-$year risk-free interest rate and $\theta_t^{(n)} = \frac{1+\mu_t^{(n)}}{1+y_t^{(n)}} - 1$ is the expected excess n-period return on $n-$period dividend risk.

We directly observe the futures price, $F_t^{(n)}$, which informs us about the market's expectation of the growth rate *by maturity* and the expected excess return, $\theta_t^{(n)}$, again, *by maturity.* The unique feature is that we can get information about growth expectations by maturity, while the stock market is informative about growth rates and expected returns across all maturities combined.

Dividend futures are exchange-traded products, traded on the Chicago Mercantile Exchange in the US and on the Eurex Exchange in EU, and also to a large extent on over-the-counter markets. Because the contracts expire in December, the maturity of the available contracts varies over the calendar year. We therefore interpolate prices across the different contracts to obtain constant maturity prices. We use the mid-quotes at close as pricing data in the US and settlement prices, which is the volume-weighted average price during the day, in the EU. We address the liquidity of the dividend futures market later in section 8. The conclusion is that trading frictions have a negligible impact on the conclusions in this paper.

Figure 4 shows how the prices on dividend futures evolve between January 1 and June 8. The figure shows the change in prices of dividend futures relative to the price of the same-maturity claim on January 1. The top left corner shows the cumulative change in prices on March 5. Prices drop only modestly during the initial spread of the virus from January 1 to March 5. In contrast, equity markets drop by more than 10% between January and early March. Since near-future dividends do not drop in value, the initial drop in the stock market must come from a drop in the value of distant-future dividends.

Dividend prices drop substantially between March 5 and March 20. The top right corner shows the change in priced from January 1 to March 20. Prices are down by more than 30% for the S&P 500 and more than 40% for the Euro Stoxx 50. The drop is biggest on the 2-year horizon. Between March 5 and March 20, stock markets drop substantially in both the US and the EU, with the S&P 500 experiencing its biggest daily loss since 1987. Important dates are March 11, when the US limits travel from the EU, and March 13, when the US declares a state of emergency. On March 13, stock markets soar after the declaration of the national emergency. Dividend prices also increase but only at the long end.

The bottom left corner shows the change in prices from January 1 to March 26. On March 25, Congress comes close to passing a 1.8 trillion dollar fiscal stimulus bill. Stock markets soar already on the March 24 following news of the bill. Overall, stock markets increase by around 10% from March 20 to March 26, presumably driven by news about stimulus.[9] However, the short-term dividend futures actually decrease slightly over this period. This finding implies that fiscal stimulus lifted the stock market by lifting the value of distant-future dividends, not by improving prices of near-term cash flows.

Finally, the bottom right corner shows the change in price from January 1 to June 8. Dividend prices increases overall between March 26 and June 8. Stock prices also increase substantially over this period, with the S&P 500 almost returning to the level of January 1

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[9] Congress is also rumored to include a ban on paying dividends until September 2020 for firms receiving financial support, something that is likely to decrease the value of the 2020 dividend claim but has less of an impact on the 2-year claim.

2020.

5 What Do Dividend Futures Tell About Growth Expectations?

5.1 A Lower Bound on Dividend Growth

We provide a simple lower bound on the expected growth rate in dividends that can be computed using market prices only. If we consider a change in the price of a dividend future over a short period of time from t to t', $t' > t$, we have

$$\Delta F_{t'}^{(n)} = \frac{\Delta G_{t'}^{(n)}}{\Delta \Theta_{t'}^{(n)}},$$

where $\Delta x_{t'} = \frac{x_{t'}}{x_t}$ and $\Theta_t^{(n)} = 1 + \theta_t^{(n)}$.

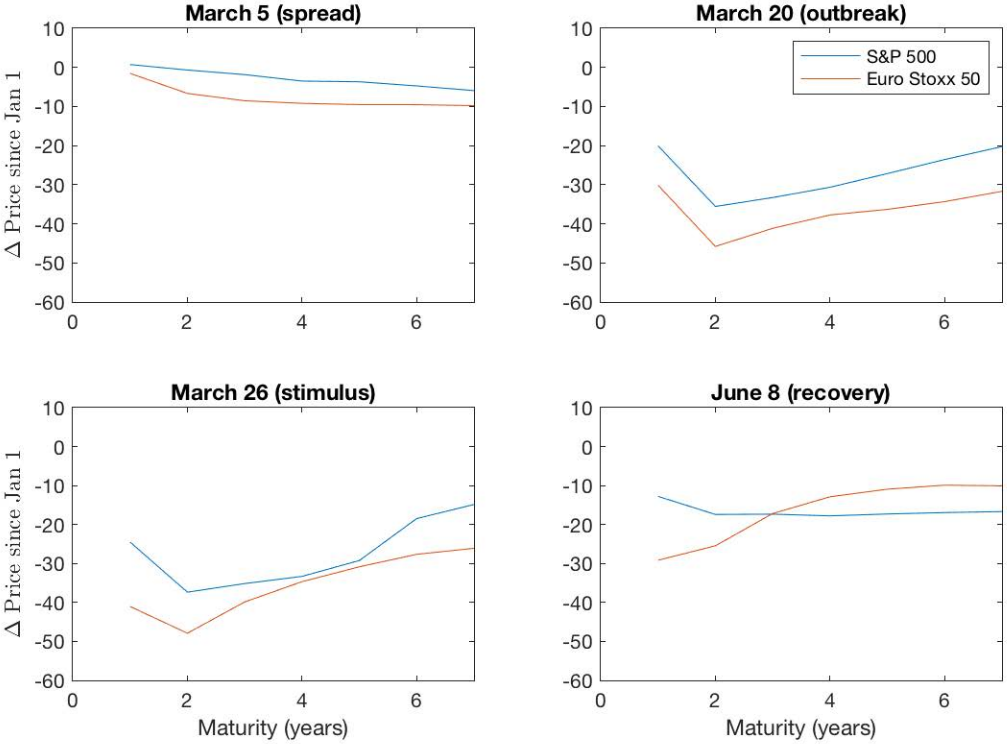
To obtain a lower bound on the change in growth expectations, our key assumption is that the expected excess return, which for instance reflects investors' risk aversion, did not decline since the outbreak, $\Delta \Theta_{t'}^{(n)} \geq 1$. This implies that we can bound the change in expected growth from below by

$$\Delta G_{t'}^{(n)} - 1 \geq \Delta F_{t'}^{(n)} - 1,$$

which depends only on market prices on the right-hand side that are readily available. Hence, the change in expected growth over the next n years, $\Delta G_{t'}^{(n)}$, is bounded from below by $\Delta F_{t'}^{(n)}$. We provide more details on the necessary technical assumptions in the Appendix.

The lower bound is shown in Figure 2 in the introduction. The lower bound on dividend growth expectations is revised down by as much as 18% in the US for the 2- to 7-year horizon. In the EU, the 1-year growth is revised down by as much as 29%. It is important to keep in mind that the lower bound represents the revision in expected growth rates relative to previous expectations, not a lower bound on the actual growth rate. If investors expected a nominal growth rate of 6% annually prior to the outbreak, the expected growth on the

Figure 4: The Development of the Dividend Term Structure over the COVID-19 Outbreak



This figure shows the relative price of dividend of dividend futures with different maturity. We consider the percentage change in prices since January 1. The dividend futures are claims on the dividend paid out on the index in a given year. We consider the S&P 500 index and the Euro Stoxx 50 index. Maturity measured on the horizontal axis is expressed in years. For instance, the top left figure shows that, between January 1 and March 5, dividend futures prices fall by only a few percent for the 2-year claim but by as much as 10% for the 7-year claim.

2-year horizon would be more than 12%. Revising the 2-year growth expectations down by 18% would thus imply a negative growth of "only" 6% over a 2-year horizon. In addition, we measure a lower bound that is equal to the actual expectations only when expected excess returns did not go up. We next discuss a methodology, which requires additional assumptions, that we use to compute an estimate of expected growth.

5.2 Estimating Dividend Growth Expectations

We estimate growth expectations directly using out-of-sample forecasting. These estimates are plotted in Figure 1. Here we explain how we estimate these. We first define the equity yields on index i as:

$$e_{it}^{(n)} = \frac{1}{n} \ln \left(\frac{D_t}{F_t^{(n)}} \right),$$

where n is measured in years. Using a training sample from 2006 to 2017, we run a pooled regression of realized dividend growth rates on the S&P 500 and the Euro Stoxx 50 onto the 2-year equity yield on the associated index:

$$\Delta_1 D_{i,t} = \beta_{0i}^D + \beta_1^D e_{it}^{(2)} + \epsilon_{i,t+4}, \tag{3}$$

where t is measured in quarters, i refers to either S&P 500 or Euro Stoxx 50, and $\Delta_n x_t \equiv \frac{x_{t+4n}}{x_t} - 1$. We then use the parameter estimates in this regression to estimate expected dividend growth at every trading day since January 1 2020. Dividends on the left hand side are measured in nominal terms. The R^2 in this forecasting regression is 0.65. We report regression details in Table 2 in the Appendix B.

6 Mapping Dividend Growth Expectations to GDP Growth Expectations

6.1 Dividend and GDP Growth

We can use dividend futures to compute a lower bound and point estimate for GDP growth expectations. Indeed, dividend expectations are related to GDP expectations as dividends summarize the profits and production of listed firms, which in turn is part of the GDP. However, there is obviously also independent variation in both series.

To illustrate the relation between the two series at the business-cycle frequency, we extract the cyclical component of real dividends and real GDP using the methodology developed in Hamilton (2018)

$$z_t = d_0 + \sum_{j=8}^{11} d_i z_{t-j} + c_t,$$

where z_t corresponds to either log real dividends or log real GDP. The residual, c_t, corresponds to the cyclical component.

Figure 5 presents the results from the first quarter in 1985 to the fourth quarter in 2019.[10] We standardize each of the series. The two move strongly together with a time-series correlation of 54%. We note that the two series are not perfectly synchronized and that the series appear more strongly related during economic downturns, that is, when the series are below average.This is precisely what we care about in the current environment, which makes dividend futures particularly relevant to estimate investors' expectation of GDP growth as well.

6.2 A Lower Bound on GDP Growth

To calculate the lower bound on changes in expected GDP growth, we multiply our lower bound on dividend growth by a country-specific constant b_i that maps dividend growth into GDP growth:

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[10] We adjust the aggregate dividend series for Microsoft's special dividend in November 2004, which otherwise would show as a substantial outlier.

$$E_t\left[\Delta_n Y_{it}\right] - 1 \geq \left(\Delta F_{i,t'}^{(n)} - 1\right) \times b_i, \tag{4}$$

where $E_t\left[\Delta_n Y_{it}\right]$ is the change in expected GDP growth at horizon n for country i. The constant b_i measures how much GDP changes when dividends change. One way to estimate b_i is to regress GDP growth on dividend growth. However, this estimate is likely to be biased downwards due to asynchronicities between the series shown in Figure 5 and other independent variation in dividend growth. A downward bias in b_i would be problematic as it leads to an upward bias in our lower bound. To ensure that our lower bound is conservative, we instead run the regression

$$\Delta_1 D_{it} = a_{0i} + a_{1i}\Delta_1 Y_{it} + \varepsilon_{t+4}, \tag{5}$$

and use $b_i = \frac{1}{a_{1i}}$. In this way, asynchronicities between GDP and dividends, and other independent variation in GDP, leads to a lower estimate of a_i and a higher estimate of b_i. This results in a more conservative lower bound.

We run separate regressions in the US and EU. In the US, we use the 1985 to 2019 sample of real growth in GDP and dividends. In the EU, we use a shorter 2003 to 2019 sample of real growth in GDP and dividends on the Euro Stoxx 50. We use real series to avoid putting too much weight on the early US sample with high inflation.[11] The resulting estimates of b_i are 0.67 in the US and 0.33 in the EU. The lower bound is plotted in Figure 6.

6.3 GDP Growth Expectations

To estimate GDP expectations, we can in principle follow the procedure of section 5.2 and use the equity yields to forecast GDP growth. However, to obtain the most accurate estimate, we want to account for (i) the small asynchronicities between GDP and dividends documented in Figure 5 and (ii) the potentially stronger relation between the two series when growth is below average, which most closely mimics the current situation.

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[11] The lower bound is nonetheless still a lower bound on nominal growth.

The sample with dividend futures is too short to effectively deal with these issues and we therefore prefer a slightly different approach. We first use the long US sample to map dividend growth into GDP growth, and we then use this mapping to transform our dividend growth expectations from section 5.2 into expectations about GDP growth. We note that one could make other reasonable modeling assumptions that may lead to somewhat different estimates.

We first map real GDP growth to real dividend growth using the following regression in the 1985-2019 US sample:

$$\Delta_n Y_t = A_n + B_n \Delta_n D_t + e_{t+4n},$$

only using data when $\Delta_n D_t < \overline{\Delta_n D_t}$, with $\bar{x} \equiv \frac{1}{T} \sum_t x_t$, and Y_t denoting real GDP. There are two important features of this regression. First, by only considering observations where realized growth is below average, we estimate the downside relation between the two series, which is what is relevant in our context. Second, by using longer horizons, n, we can mitigate the effect of small asynchronicities.

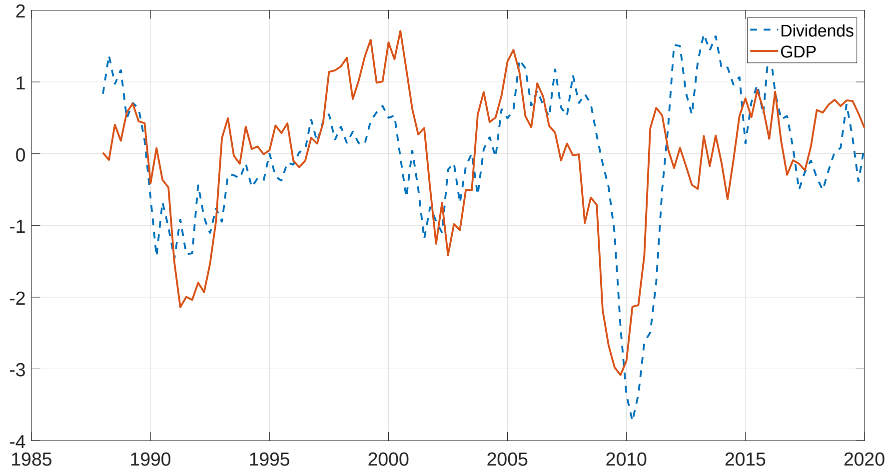
As our benchmark case, we estimate B_n using 2-year growth ($n = 2$) in the 1985 to 2019 US sample. The baseline estimate is 0.22, meaning that dividends move approximately four times as much as GDP in downturns (see Table 3 in the Appendix for details). The baseline estimate is robust to using a longer sample period and to using 3- instead of 2-year growth, as reported in the Appendix B. The estimate is lower if we consider 1-year growth, reflecting that GDP and dividends are not perfectly synchronized. If we consider the unconditional relation between GDP and dividends, the slope coefficient is only half as large, suggesting a weaker upside relation between GDP and dividend growth.

Having estimated the relation between GDP and dividends, we forecast GDP growth as:

$$E_t \left[\Delta_1 Y_{it} \right] = A_i + B_2 \beta_1^D e_{i,t}^{(2)},$$

where A_i can be chosen such that our forecast is correct on average in the 2006 to 2017 sample (the constant is irrelevant as we forecast the change in expectations since January 2020, which only depends on the slope coefficients and the dividend yield). We use the same estimate of B_n, which is based on US data, for both the US and the EU, as we have a longer

Figure 5: Cyclical components of log real dividends and log real GDP.



sample available for the US. We emphasize once more that these estimates are based on a forecasting model estimated using historical data. In unprecedented times, there is a risk that historical relations change, implying that these estimates come with uncertainty.

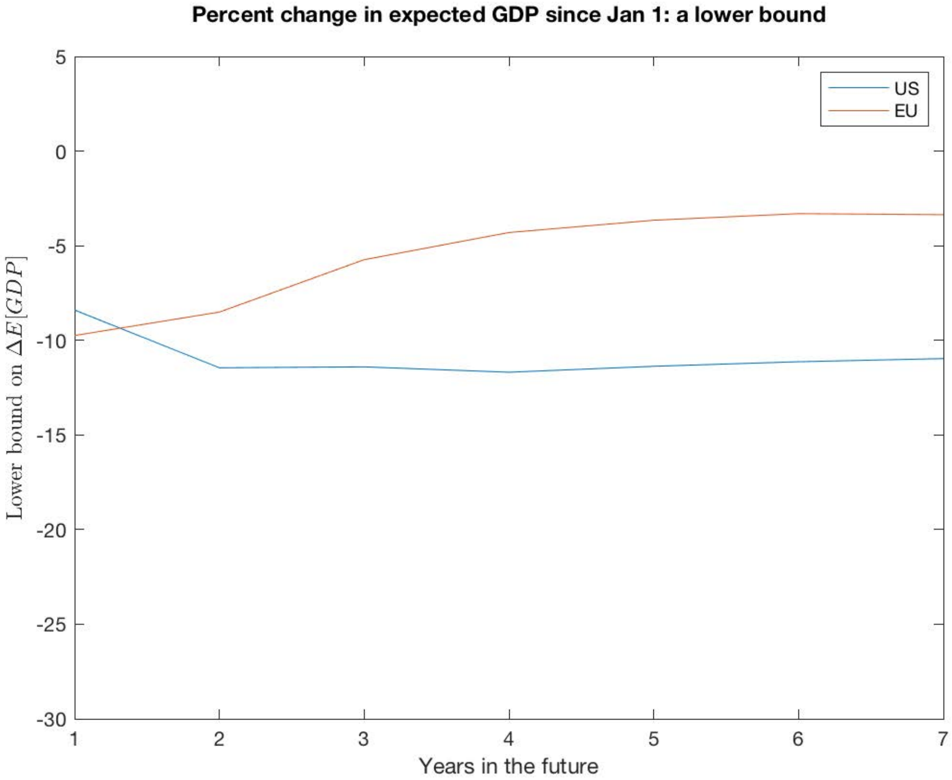
For comparison, we also show a series of contemporary GDP forecasts in Table 1 until the middle of March. We also refer to the CEPR book on "Economics in the Time of COVID-19" for further analysis of the economic effects, and in particular the chapter by Wren-Lewis (2020) who estimates a decline of GDP of around 1% to 2%, and at most 5%.

7 Comparison to the Global Financial Crisis of 2008

We compare the market's response to COVID-19 to the GFC of 2008. On March 23, the VIX is at a similar level as the one observed during the GFC. Stock prices have also dropped as much as in the fall of 2008, at least when measured in excess of 30-year treasuries. These observations underline the severity of the impact of the COVID-19 outbreak on financial markets.

Figure 7 shows the lower bound during the GFC. The blue line plots the lower bound on revisions in expected dividends between July 31 2008 and November 31 2008. The red line

Figure 6: A lower bound on GDP growth expectations by maturity as implied by dividend markets



The figure shows a lower bound on changes in expected GDP at the 1 to 7-year horizon. The changes are measured relative to expectations on January 1. The figure shows that expected GDP may have been revised down by as much as 31% in the US and 19% in the EU. It is revised down the most on the 1- to 2-year horizon. This estimate is a lower bound meaning actual expectations are likely be higher (see text for description).

Table 1: GDP growth forecasts

Organization company	**Period**	**Change**	**Level**	**Region**	**Date**
Office for Budget Responsibility	2020	-0.30%		Britain	12-Mar
Rabobank	2020.H1		Below last year's level	EU	12-Mar
EUan Commission	2020	-2.30%		EU	13-Mar
Rabobank	2020	-1%		Eurozone	12-Mar
Rabobank	2020	-0.60%		France	12-Mar
Berenberg Bank	2020.Q1	-0.10%		Germany	19-Feb
Rabobank	2020	-0.90%		Germany	12-Mar
OECD	2020	-0.50%		Global	3-Feb
IMF	2020	-0.10%		Global	22-Feb
IMF	2020		Below last year's level	Global	4-Mar
Goldman Sachs	2020	-1%		Global	6-Mar
Moody's	2020	-0.30%		Global	10-Mar
Rabobank	2020	-1.30%		Global	12-Mar
Rabobank	2020	-1.70%		Italy	12-Mar
Rabobank	2020	-0.60%		Netherlands	12-Mar
Rabobank	2020	-0.50%		Spain	12-Mar
Rabobank	2020	-0.50%		UK	12-Mar
Goldman	2020.Q1	-1.10%		US	2-Mar
OECD	2020.Q2		Below last year's level	US	6-Mar
WSJ Survey among economists	2020	-0.70%		US	12-Mar
Rabobank	2020	-0.50%		US	12-Mar
Capital Economist	2020.Q2	-1%		US	13-Mar
Bank of America	2020	-0.40%		US	14-Mar
Bruce Kasman (JPMorgan)	2020.H1		Below last year's level	US & Global	13-Mar

plots the subsequent realized dividends measured relative to a pre-crisis trend of around 4% growth.[12] For the S&P 500, the lower bound on changes in expected dividends lines up well with the realized dividends at the short-end. For Euro Stoxx 50, realizations are slightly below the bound at the short end, above the bound in the middle, and around the bound at the long end.[13] It is comforting that even during a period of high financial turbulence, the future prices appear well linked to fundamentals and align well with realizations.

Figure 7 also plots the lower bound following the outbreak of COVID-19. On March 23, which is the day the stock market reaches the bottom, the bound is lower than observed during the financial crisis, but the curve indicates more catch-up growth, particularly in Europe.

8 Liquidity of the Dividend Futures Market

Dividend futures for the Euro Stoxx 50 have traded on the Eurex exchange since 2008. The size of the market has increased steadily since its inception as shown in Figure 8. At the end of 2019, there are around 1 million contracts outstanding. Each contract is for a 100 dividend points and trades at around EUR 12,000 depending on the maturity. This gives a total notional outstanding of around EUR 12 billion. The total number of contracts increases from around 800,000 to 1,200,000 during the spring of 2020, but the notional measured in EUR drops because the value of the futures decreases.

Figure 9 shows the number of contracts traded daily. The trading volume increases during the coronavirus crisis, peaking at 100,000 daily contracts. As a comparison, the average daily traded contracts in 2019 is around 20,000. This heightened volume alleviates concerns that the market dried up during the crisis.

The average bid-ask spread varies with the maturity of the claim. Between January 1 and May 19, the bid-ask spread for the 2021 claim is on average 0.27% in the middle of the day. The bid-ask spread increases steadily in the maturity of the contract to around 1.2%

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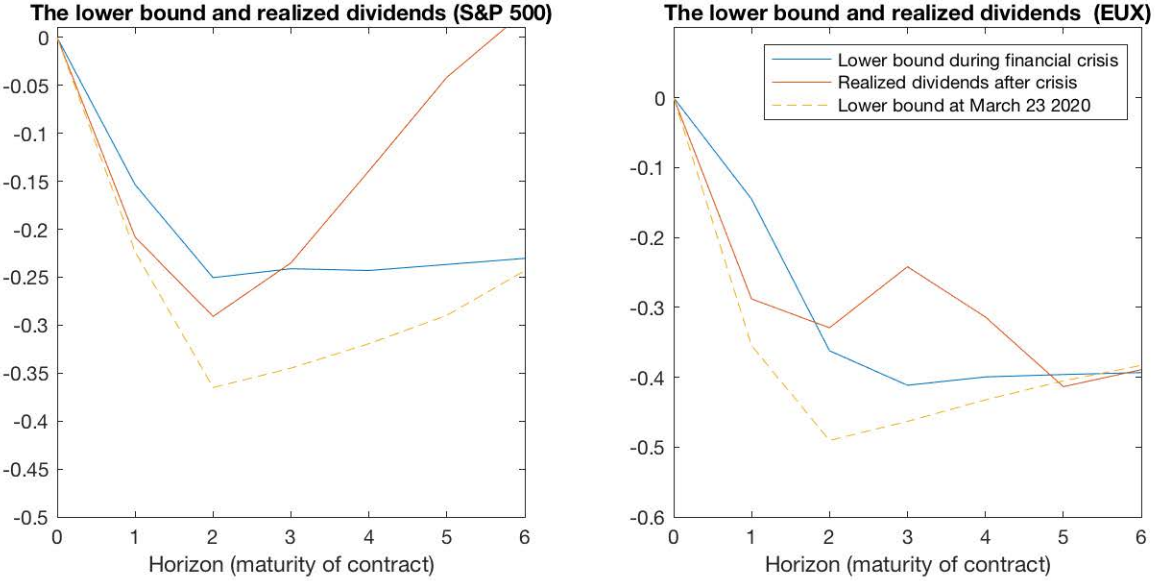
[12] We measure the growth rates as the real-growth in dividends observed between 1947 and 2007, which is close to 2% plus 2% for expected long-run inflation in 2007.

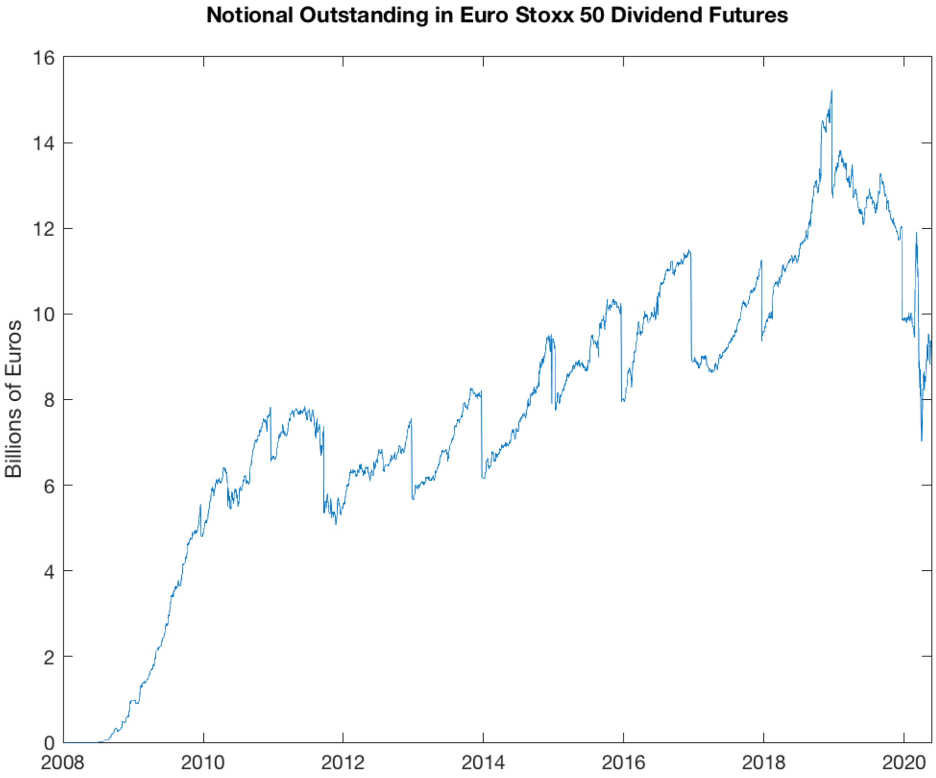
[13] We note, however, that the low realized dividends on the long end could reflect the European sovereign debt crisis of 2011, which was probably unexpected in 2008.

Figure 7: Comparing the Lower bound to the lower bound observed during the Global Financial Crisis



The blue line shows the lower bound on changes in expected dividend growth between between July 31 and November 31 in 2008. The line shows that dividend growth was revised down with up to 25% on the 2-year horizon for the S&P 500. The red line shows the realized dividends x years into the future (relative to a pre-crisis trend of 4% nominal). The realized dividends where approximately 30% below the pre-crisis trend after 2 years for the S&P 500. The dotted yellow line shows the lower bound on changes in expected dividend growth between January 1 and June 8 2020. The lower bound is as lower than observed during the financial crisis. The figure shows results for the S&P 500 to the left and for Euro Stoxx 50 to the right.

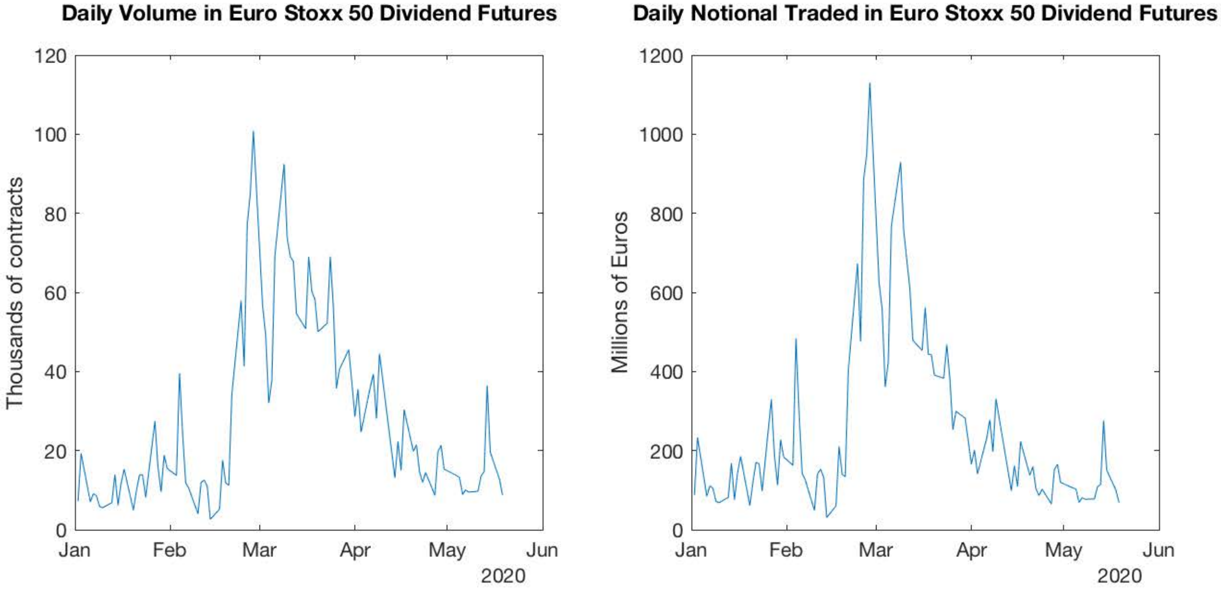
Figure 8: Notional Outstanding for Euro Stoxx 50 Dividend Futures



This figure shows the total notional outstanding on Euro Stoxx 50 dividend futures on the Eurex exchange.

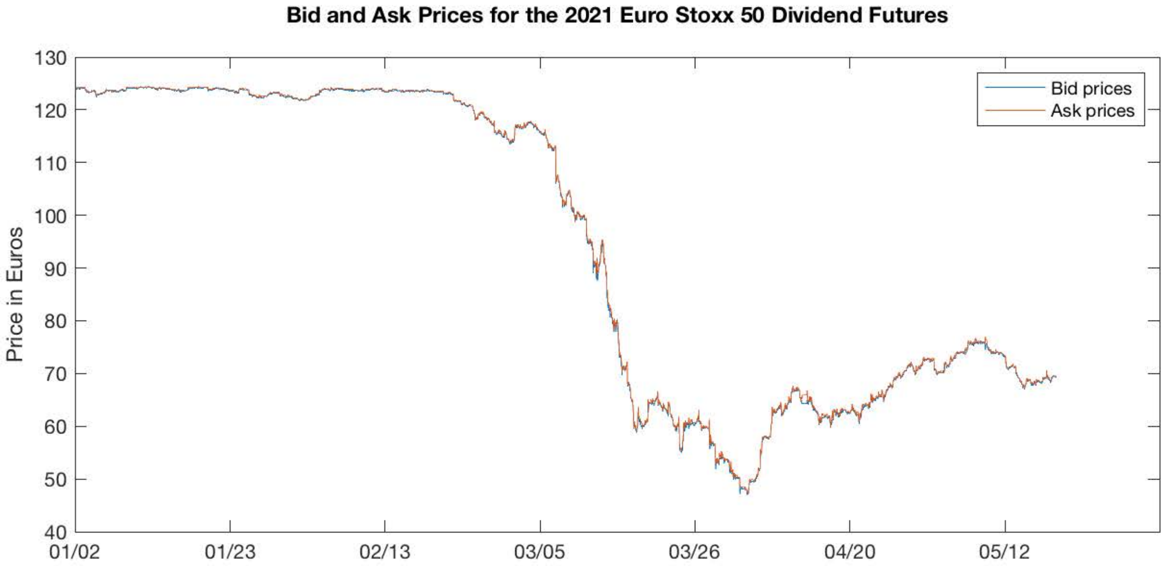
for the 2027 claim. We note that bid-ask spreads vary over day and tend to be larger in the morning, before the cash market on European exchanges starts trading, and in the evening, after the cash markets closes (the futures themselves trade from 8:30 to 22:00). Figure 10 shows the bid and ask prices for the 2021 claim. We measure the average bid and ask prices over each 15-min interval during opening hours of the cash market in Frankfurt (that is, from 9:00 to 17:30). The bid and ask prices are close at all points in the sample.

Figure 9: Daily Volume in the Market for Euro Stoxx 50 Dividend Futures



The left side of this figure shows the daily volume traded in the market for Euro Stoxx 50 dividend futures. Each contract is for 100 dividend points. The right side of the figure shows the total value of the contracts traded on a given day. Sample is Jan 1 to May 19 2020.

Figure 10: Bid and Ask Prices for the 2021 Euro Stoxx 50 Dividend Claim



This figure shows the bid and ask prices of the 2021 Euro Stoxx 50 dividend futures. The figure shows the average price over each 15-minute interval. We only consider the prices during the time of the day where the Frankfurt Stock Exchange is open for trading in the cash equity market (9:00-17:30). Sample is Jan 1 to May 19 2020.

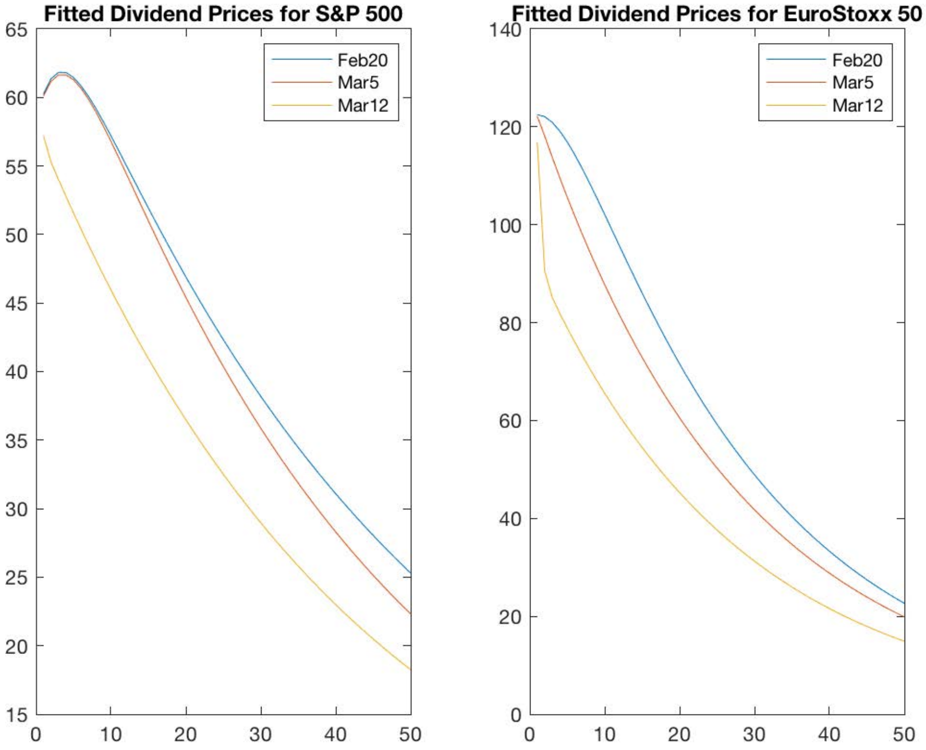
9 Reconciling the Price of the Stock Market with Dividend Strip Prices

Given the modest decline in growth expectations in the first weeks of the outbreak, we can learn something about how expected excess returns changed during this period. To illustrate this, we fit a simple model for dividend prices that we require to simultaneously price the dividend futures as well as the aggregate stock market. Starting from (1), we observe the dividend prices for the first 7 years and we observe S_t. We model the expected growth minus the expected excess return, $g_t^n - \theta_t^n$, as a function of maturity. The functional form that we fit in each period follows Nelson and Siegel (1987).

The results are presented in Figure 11. As the short-term dividend prices in the US did not move much for the first 7 years, even though the market fell, from February 20 to March 5, the long-term dividend prices fell. The expected value of short-term dividends is likely to fall more than the expected value of long-term dividends as some catch-up growth is expected. The large drop in the value of long-term dividend must therefore come from an increase in discount rates. Increases in expected returns on long-term claims is commonly observed during times of stress (Gormsen (2020)). In the EU, both short- and long-term dividend prices dropped during the same period, which is more consistent with a shock to both growth expectations and expected excess returns. During the period from March 5 to 12, in which growth expectations changed sharply, we see that both short- and long term dividend prices fell sharply in both geographies.

These results have implications for asset pricing theories. It is well known that it is oftentimes difficult to identify the economic shocks that caused asset prices to move (Cutler et al. (1989)). The unique feature of the ongoing events is that the nature of the shock is clear, as well as the temporal structure. Although there is uncertainty about the long-term consequences, it seems reasonable to assume that the short-term economic growth consequences are more severe than the consequences after, say, five years. Moreover, the initial decline in the aggregate stock market in the US, with a small response to short-term dividend prices, suggests that modest shocks to short-term expectations can trigger large and persistent changes in expected excess returns.

Figure 11: Reconciling the stock market and dividend price responses



This figure shows estimated prices of dividends for different maturity. For both S&P 500 and Euro Stoxx 50, we fit the term structure of dividend prices to the functional form on Nelson and Siegel (1987) under the restriction that the price of all the dividends sum to the market. We estimate the prices separately on February 20, March 5, and March 12. Maturity measured on the horizontal axis is in years.

10 A Simple of Theory of Pandemics and Asset Prices

We propose a simple model to provide a more structural interpretation of the key facts that we document empirically.

10.1 Model Specification

Time is indexed by t and all shocks in the model have a standard normal distribution. We distinguish three phases in the model: (i) the period before the pandemic, (ii) the initial outbreak and containment period, and (iii) the period after the virus. During the first period, $t < t_0$, log dividend growth, Δd_t, has a constant mean and variance,

$$\Delta d_t = \mu_N - \frac{1}{2}\sigma_N^2 + \sigma_N \epsilon_t^N.$$

We summarize investors' preferences via the stochastic discount factor (SDF), M_t, that is given by

$$M_t = \exp\left(-y - \frac{1}{2}\lambda^2 - \lambda\epsilon_t^N\right).$$

In this simple environment, the prices of dividend futures, normalized by the current level of dividends, $FD_t^{(n)}$, are given by

$$FD_t^{(n)} = \exp\left(n\mu^\star\right),$$

with $\mu^\star = \mu - \sigma\lambda$. We assume that investors did not anticipate the arrival of a pandemic during this period. As such, we cannot learn about the risk, or pricing of pandemic risks, during this period.

During the second period, $t \in [t_0, t_1)$, the virus spreads and behavioral or regulatory social distancing measures are put in place. As a result, dividends decline,

$$D_t = D_{t_0}\exp\left(-\varphi_t\right),$$

with $\varphi_t \geq 0$ for $t \in [t_0, t_1)$. We refer to φ_t as the *cost of social distancing.* These costs are uncertain and evolve as

$$\Delta\varphi_t = \sigma_\varphi \epsilon_t^\varphi,$$

which is the first source of pandemic-specific risk.

At $t = t_1$, the pandemic ends and we assume for simplicity that dividends recover to pre-crisis levels, $D_{t_1} = D_{t_0}$.[14] However, there is uncertainty about the long-run damage done during the economy's shutdown. Defaults among firms and households can weaken the balance sheets of the financial sector and the recession may escalate into a financial crisis. This financial disaster, if it were to happen, occurs at $t = t_1$.

If the disaster does not happen, relative dividend futures prices restore to pre-crisis levels

$$FD_t^{(n)} = \exp\left(n\mu^\star\right),$$

for $t \geq t_1$. However, if a financial crisis does happen, relative dividend futures prices are permanently lowered for $t \geq t_1$,

$$FD_t^{(n)} = \exp\left(n\mu^\star\rho\right),$$

with $\rho \in (0,1)$. As $\mu^\star = \mu - \sigma\lambda < 0$, a lower risk-neutral growth rate is consistent with a lower rate of economic growth, higher uncertainty or higher risk prices, for instance, due to an increase in investors' risk aversion. The possibility of a financial crisis is the second source of pandemic-specific risk.

The probability of a disaster at t_1, given the information at time $t_1 - 1$, is given by

$$\pi_{t_1-1} = \pi_0 \exp\left(g_{t_1-1} + \varphi_{t_1-1}\right),$$

which implies that the probability is increasing in the cost of social distancing, φ_{t_1-1}. The disaster probability is also increasing in g_{t_1-1}, which are additional factors that increase the probability of a financial crisis. For instance, g_t may decrease (or become negative) as a result of fiscal or monetary policy actions. Alternatively, g_t may increase due to concerns about defaults among households and small firms that weaken (shadow) banks' balance sheets but

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[14] In reality, dividends tend to recover more gradually. Adding this feature to the model does not affect the basic economics at work and we omit it to keep the model as stylized as possible.

are not perfectly correlated with φ_t. We refer to g_t as *financial crisis concerns.*

As φ_t and g_t are both equal to zero for $t < t_0$, π_0 reflects the unconditional probability of a disaster once the pandemic starts. The dynamics of g_t is

$$\Delta g_t = \sigma_{g\varphi}\epsilon_t^{\varphi} + \sigma_g \epsilon_t^g, \tag{6}$$

where the first term, $\sigma_{g\varphi}\epsilon_t^{\varphi}$, captures the correlation between the cost of social distancing and financial crisis concerns. The shock ϵ_t^g captures the independent variation, and we assume $\mathbb{E}_t\left[\epsilon_{t+1}^g \epsilon_{t+1}^{\varphi}\right] = 0$.

Uncertainty about government interventions is the third and final source of pandemic-specific risk. During the outbreak of the pandemic, which is the period covered by our paper, asset prices are driven by just two shocks: ϵ_t^{φ} and ϵ_t^g. Short-term dividend prices are less impacted by government policy actions than the market itself, or long-term dividend prices, as a financial disaster has a larger impact on longer-term claims.

To complete the model, we specify how investors price risk when $t \in [t_0, t_1)$. The SDF is given by

$$M_t = \exp\left(-y - \lambda^2 + \lambda\epsilon_t^{\varphi} + \lambda\epsilon_t^g\right),$$

where we assume for simplicity that the risk prices on all shocks are identical. Given the short sample, we do not have enough power to separately estimate risk prices on different sources of risk. Moreover, we are primarily interested in the dynamics of g_t, φ_t, and π_t, for which the risk prices are not important as we will show.

10.2 Model Solution

We solve for the relative dividend futures prices, $FD_t^{(n)}$, for the second period when $t \in [t_0, t_1)$. The dividend prices for $n < t_1 - t$ are given by

$$FD_t^{(n)} = \exp\left(c_{0,n}\right),$$

and for $n \geq t_1 - t$, we have

$$FD_t^{(n)} = \exp\left(a_{0,n} + a_{1,n}\varphi_t\right) - \exp\left(b_{0,n} + b_{1,n}\varphi_t + b_{2,n}g_t\right), \tag{7}$$

and we derive the expressions for the coefficients in Appendix C.

10.3 Model Implications

For the short-term dividend prices, we consider the case where $n < t_1 - t$. This implies that short-term dividend futures directly reveal φ_t as

$$\ln F_t^{(n)} - \ln F_{t_0^-}^{(n)} = c_{0,n} - \mu^\star n + \ln D_t - \ln D_{t_0^-} = c_{0,n} - \mu^\star n - \varphi_t, \tag{8}$$

where we ignore the declining maturity over a short period of time in calculating the constant.

Equity prices depend on φ_t and g_t, which implies that short-term dividend futures prices and the market together allow us to uncover both (g_t, φ_t). The value of the stock market, S_t, relative to the current level of dividends, D_t, is denoted by SD_t and given by

$$\begin{aligned} SD_t &= \sum_{n=1}^{\infty} \exp\left(-y_t^{(n)} n\right) FD_t^{(n)} \\ &= \sum_{n=1}^{t_1-t-1} \exp\left(-y_t^{(n)} n + c_{0,n}\right) + \\ & \sum_{n=t_1-t}^{\infty} \exp\left(-y_t^{(n)} n + a_{0,n} + a_{1,n}\varphi_t\right) - \exp\left(-y_t^{(n)} n + b_{0,n} + b_{1,n}\varphi_t + b_{2,n} g_t\right). \end{aligned}$$

As before, we consider

$$\begin{aligned} & \ln S_t - \ln S_{t_0^-} \\ &= \ln SD_t - \ln SD_{t_0^-} + \ln D_t - \ln D_{t_0^-} \\ &= \ln SD_t - \ln SD_{t_0^-} - \varphi_t. \end{aligned}$$

This shows that based on movements in stock prices, bond yields, and dividend futures prices (which allow us to measure φ_t), we can recover g_t. Based on dividend futures prices alone, we can recover φ_t, see (8). To simplify the calculations, we linearize the price-dividend ratio around the price-dividend ratio right before the pandemic. In Appendix C, we show that this implies

$$\varphi_t \simeq constant - \left(\ln F_t^{(n)} - \ln F_{t_0^-}^{(n)}\right), \tag{9}$$

$$g_t \simeq constant - \left(\ln S_t - \ln S_{t_0^-}\right) - \sum_{n=1}^{\infty} \theta_t^n n \left(y_t^{(n)} - y_{t_0^-}^{(n)}\right) - \varphi_t, \tag{10}$$

where the expression for $\theta_{t_0^-}^{(n)}$ is given in equation (13).

With both series in hand, we can also compute the relative change in the disaster probability

$$\frac{\pi_t}{\pi_{t_0}} = \exp\left(g_t + \varphi_t\right). \tag{11}$$

10.4 Results

In estimating φ_t and g_t, we set $\mu^\star = -2\%$. We report all series relative to their values on February 20 as in Figure 11. The results are reported in Figure 12. The left panel displays the cost of social distancing, which is directly linked to the decline in dividend futures, see (10). To estimate the series, we use the 2-year dividend futures contract. The middle panel shows our estimates of financial crisis concerns, g_t. The right panel compute the relative disaster probability, see (11). As the government bond market experienced substantial stress in March, which leads to large swings in bond yields, we report the 7-day moving average as the red line.[15]

We find that the cost of social distancing rises sharply in March and peaks at approximately 55% in the beginning of April. The cost sharply declines early April and stabilizes until the middle of May. As of then, the cost falls sharply once again to 25%. The financial crisis concerns, in the middle panel, increase sharply from the middle of February, even though the expected cost of social distancing are still low. This illustrates the rapidly rising concern of a potential downturn, by 20% in a 2-week period, but not in the immediate future. Such sentiment has a larger impact on the stock market compared to dividend futures. As the cost of social distancing rises, g_t declines. This presumably reflects investors'

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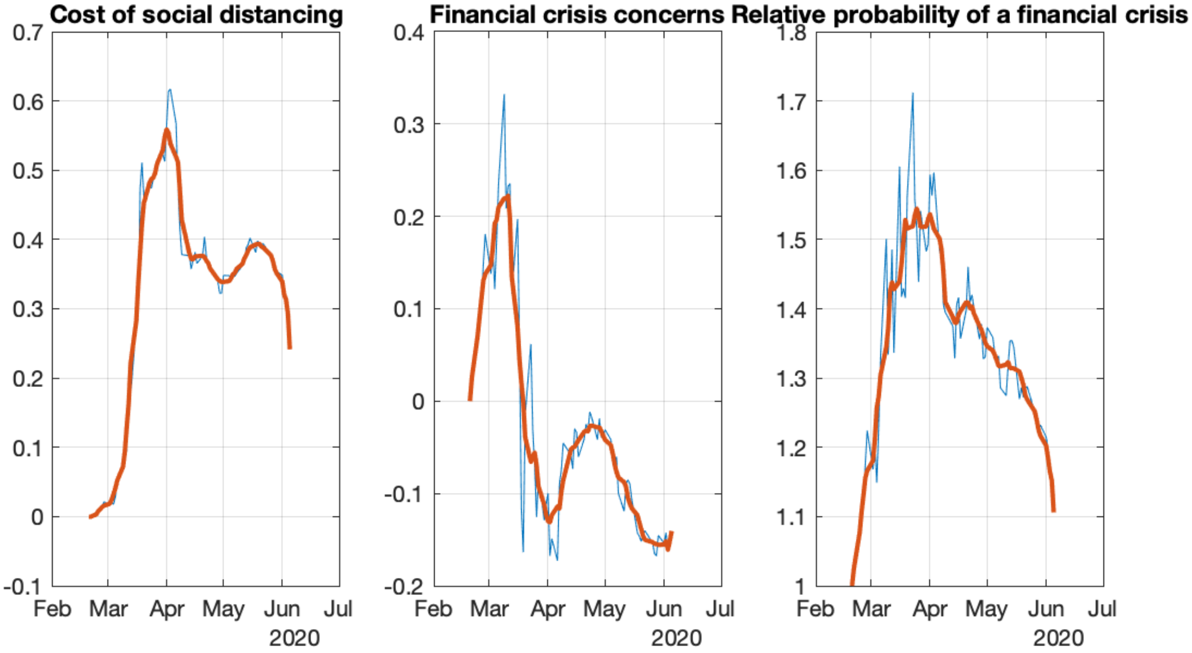
[15] We smooth the series 3 days backwards and 3 days forward, leading to a 7-day window including the current day.

Figure 12: Dynamics of the cost of social distancing, financial crisis concerns, and the relative probability of a financial crisis.



expectations about fiscal and monetary policy actions.

The right panel reports the relative disaster probability, where the probability is relative to its value on February 20. We find that the disaster probability increases by 55%, and subsequently steadily declines. However, by the end of our sample, it is still 10% higher compared to February 20. This is even though the stock market recovered to pre-crisis levels. The reason is that long-term bond yields declined during this period. As a result, stock prices should have increased substantially more if the disaster probability would have reduced to February 20 levels. This implies that even though expected returns may be the same as before the crisis, the expected return *in excess of risk-free bonds* is likely still elevated.

11 Conclusion

In periods of economic and financial distress, getting frequently-updated and forward-looking measures of the expected path of the economy is key for policy makers and market participants. We show that dividend futures can constitute a useful tool in this regard.

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A Technical Details of the Lower Bounds

In this appendix, we detail the assumptions we use to derive a lower bound on dividend (in Section A.1) and GDP growth rates (in Section A.2).

A.1 Dividend Growth

We derive the lower bound for the one-period dividend growth expectations and the arguments directly extend to longer-term growth expectations. By no arbitrage, the price of a one-period dividend futures, $F_t^{(1)}$, is given by

$$F_t^{(1)} = \frac{\mathbb{E}_t[M_{t+1}D_{t+1}]}{\mathbb{E}_t[M_{t+1}]},$$

where M_{t+1} denotes the stochastic discount factor. We rewrite the equation as

$$\frac{F_t^{(1)}}{D_t} = \frac{\mathbb{E}_t\left[M_{t+1}\frac{D_{t+1}}{D_t}\right]}{\mathbb{E}_t[M_{t+1}]},$$

and using $\mathbb{E}\left[XY\right] = \mathbb{E}\left[X\right]\mathbb{E}\left[Y\right] + Cov\left(X, Y\right)$, we have

$$\begin{aligned}\frac{F_t^{(1)}}{D_t} &= G_t^{(1)} + \frac{Cov\left(M_{t+1}, \frac{D_{t+1}}{D_t}\right)}{\mathbb{E}_t[M_{t+1}]}, \\ &= \frac{G_t^{(1)}}{\Theta_t^{(1)}},\end{aligned}$$

where

$$\Theta_t^{(1)} = \left[1 + \frac{Cov\left(M_{t+1}, \frac{D_{t+1}}{D_t}\right)}{\mathbb{E}_t[M_{t+1}]G_t^{(1)}}\right]^{-1},$$

is the (gross) risk premium on dividend growth. Our central assumption is that following the crisis at $t' > t$, investors's risk aversion increases, implying $\Theta_{t'}^{(1)} \geq \Theta_t^{(1)}$. As a result, we have

$$
\begin{aligned}
\frac{F_{t'}^{(1)}}{F_t^{(1)}} &= \frac{G_{t'}^{(1)}}{G_t^{(1)}} \frac{\Theta_t^{(1)}}{\Theta_{t'}^{(1)}} \\
&\leq \frac{G_{t'}^{(1)}}{G_t^{(1)}},
\end{aligned}
$$

which yields the lower bound

$$\frac{G_{t'}^{(1)}}{G_t^{(1)}} \geq \frac{F_{t'}^{(1)}}{F_t^{(1)}}. \tag{12}$$

A.2 GDP Growth

To derive a lower bound on GDP growth, we start from a regression as in (5), where we regress dividend growth on GDP growth

$$\frac{D_{t+1}}{D_t} - 1 = \alpha_0 + \alpha_1 \left[\frac{Y_{t+1}}{Y_t} - 1\right] + \epsilon_{t+1}.$$

Taking conditional expectations and rewriting gives

$$
\begin{aligned}
\frac{G_{t'}^{(1)}}{G_t^{(1)}} &= \frac{1 + \alpha_0 + \alpha_1 E_{t'}\left[\frac{Y_{t+1}}{Y_t} - 1\right]}{1 + \alpha_0 + \alpha_1 E_t\left[\frac{Y_{t+1}}{Y_t} - 1\right]}, \\
&\simeq 1 + \alpha_1 \left(E_{t'}\left[\frac{Y_{t+1}}{Y_t}\right] - E_t\left[\frac{Y_{t+1}}{Y_t}\right]\right)
\end{aligned}
$$

using that $\alpha_0 \simeq 0$ and that $\frac{1+x}{1+y} - 1 \simeq x - y$ for (x, y) small. The above step assumes that expectations about ϵ are not updated between $t$and t'. Inserting into 12 and using $\frac{1+x}{1+y} - 1 \simeq x - y$ again gives

$$\frac{\mathbb{E}_{t'}\left[\frac{Y_{t+1}}{Y_t}\right]}{\mathbb{E}_t\left[\frac{Y_{t+1}}{Y_t}\right]} - 1 \geq \frac{1}{\alpha_1}\left[\frac{F_{t'}^{(1)}}{F_t^{(1)}} - 1\right].$$

Table 2: Predictive Regressions of Dividend Growth on Dividend Yields

This table shows results from regressions similar to (3). In a pooled sample across S&P 500 and Euro Stoxx 50, we regress realized dividend growth onto the ex-ante two-year yield and a dummy equal to 1 for Euro Stoxx 50 observations. HAC standard errors based on (Lazarus et al., 2019) are presented in parenthesis. Observations are quarterly.

	Intercept	EU dummy	$e_{it}^{(2)}$	R^2	# Obs
$\Delta_1 D_{i,t}$	0.046	-0.018	-0.9518	0.65	98
	(0.02)	(0.03)	(0.19)		

B Additional Tables

C Model Solution

First, for $n < t_1 - t$, we have $FD_t^{(n)} = \exp\left(c_{0,n}\right)$ and we can solve for the coefficients using

$$\begin{aligned} FD_t^{(n)} &= \frac{\mathbb{E}_t\left[M_{t+1} FD_{t+1}^{(n-1)} \frac{D_{t+1}}{D_t}\right]}{\mathbb{E}_t\left[M_{t+1}\right]} \\ &= \mathbb{E}_t\left[\exp\left(-\frac{1}{2}\lambda^2 + \lambda \epsilon_t^{\varphi}\right) \exp\left(c_{0,n-1} - \sigma_{\varphi}\epsilon_{t+1}^{\varphi}\right)\right] \\ &= \exp\left(c_{0,n-1} + \frac{1}{2}\sigma_{\varphi}^2 - \lambda\sigma_{\varphi}\right) \\ &= \exp\left(c_{0,n}\right), \end{aligned}$$

implying

$$c_{0,n} = c_{0,n-1} + \frac{1}{2}\sigma_{\varphi}^2 - \lambda\sigma_{\varphi}.$$

For $n \geq t_1 - 1$, the prices take the form as announced in (7). We first consider $t = t_1 - 1$, for which it holds:

Table 3: Mapping Dividends to GDP

This table shows the slope coefficient B_n for a regression of GDP growth onto dividend growth at different horizons (n), conditions and sample periods. The baseline coefficient is estimated in the 1985-2019 sample using using rolling 2-year growth and only considers observations where realized dividend growth is below the time-series average. Dividend growth is real dividend growth for S&P 500 and GDP growth is real GDP growth in US. HAC standard errors based on (Lazarus et al., 2019) are presented in parenthesis. Observations are quarterly.

	Baseline:	Robustness					
Horizon (years)	2	1	3	2	3	2	3
Condition:	Downside	Downside				Unconditional	
Sample:	1985-2019	1985-2019		1958-2019		1985-2019	
B_n	0.22	0.14	0.31	0.23	0.27	0.13	0.12
s.e.	(0.03)	(0.05)	(0.04)	(0.07)	(0.11)	(0.06)	(0.07)
R^2	0.50	0.18	0.67	0.19	0.23	0.14	0.12
Observations	62	66	62	125	131	240	236

$$
\begin{aligned}
FD_{t_1-1}^{(n+1)} &= \frac{\mathbb{E}_{t_1-1}\left[M_{t_1} FD_{t_1}^{(n)} \exp\left(\Delta d_{t_1}\right)\right]}{\mathbb{E}_{t_1-1}\left[M_{t_1}\right]} \\
&= \left(1-\pi_{t_1-1}\right)\exp\left(n\mu^{\star}\right)\exp\left(\varphi_{t_1-1}\right) \\
&+ \pi_{t_1-1}\exp\left(n\mu^{\star}\rho\right)\exp\left(\varphi_{t_1-1}\right) \\
&= \exp\left(n\mu^{\star}\right)\exp\left(\varphi_{t_1-1}\right) \\
&- \left(\exp\left(n\mu^{\star}\right) - \exp\left(n\mu^{\star}\rho\right)\right)\pi_0 \exp\left(g_{t_1-1} + \left(1+\xi\right)\varphi_{t_1-1}\right) \\
&= \exp\left(a_{0,n+1} + a_{1,n+1}\varphi_{t_1-1}\right) - \exp\left(b_{0,n+1} + b_{1,n+1}\varphi_{t_1-1} + b_{2,n+1} g_{t_1-1}\right),
\end{aligned}
$$

implying

$$
\begin{aligned}
a_{0,n} &= \left(n-1\right)\mu^{\star}, \\
a_{1,n} &= 1, \\
b_{0,n} &= \ln\left(\exp\left(\left(n-1\right)\mu^{\star}\right) - \exp\left(\left(n-1\right)\mu^{\star}\rho\right)\right) + \ln\pi_0, \\
b_{1,n} &= 1+\xi, \\
b_{2,n} &= 1.
\end{aligned}
$$

For $t \in [t_0, t_1 - 1)$, we recursively solve for prices

$$
\begin{aligned}
FD_t^{(n+1)} &= \frac{\mathbb{E}_t\left[M_{t+1} FD_{t+1}^{(n)} \exp\left(\Delta d_{t+1}\right)\right]}{\mathbb{E}_t\left[M_{t+1}\right]} \\
&= \mathbb{E}_t\left[\frac{M_{t+1}}{\mathbb{E}_t\left[M_{t+1}\right]} \exp\left(a_{0,n} + a_{1,n}\varphi_t + \left(a_{1,n}-1\right)\sigma_\varphi \epsilon_{t+1}^{\varphi}\right)\right] \\
&- \mathbb{E}_t\left[\frac{M_{t+1}}{\mathbb{E}_t\left[M_{t+1}\right]} \exp\left(b_{0,n} + b_{1,n}\varphi_t + b_{2,n} g_t + \left(\left(b_{1,n}-1\right)\sigma_\varphi + b_{2,n}\sigma_{g\varphi}\right)\epsilon_{t+1}^{\varphi} + b_{2,n}\sigma_g \epsilon_{t+1}^{g}\right)\right] \\
&= \exp\left(a_{0,n} + a_{1,n}\varphi_t + \frac{1}{2}\left(a_{1,n}-1\right)^2 \sigma_\varphi^2 + \left(a_{1,n}-1\right)\sigma_\varphi \lambda\right) \\
&- \exp\left(b_{0,n} + b_{1,n}\varphi_t + b_{2,n} g_t + \frac{1}{2}\left(\left(b_{1,n}-1\right)\sigma_\varphi + b_{2,n}\sigma_{g\varphi}\right)^2\right) \\
&\times \exp\left(\frac{1}{2} b_{2,n}^2 \sigma_g^2 + \left(\left(b_{1,n}-1\right)\sigma_\varphi + b_{2,n}\sigma_{g\varphi} + b_{2,n}\sigma_g\right)\lambda\right),
\end{aligned}
$$

implying

$$
FD_t^{(n)} = \exp\left(a_{0,n} + a_{1,n}\varphi_t\right) - \exp\left(b_{0,n} + b_{1,n}\varphi_t + b_{2,n} g_t\right),
$$

where

$$
\begin{aligned}
a_{0,n} &= a_{0,n-1} + \frac{1}{2}\left(a_{1,n-1}-1\right)^2 \sigma_\varphi^2 + \left(a_{1,n-1}-1\right)\sigma_\varphi \lambda, \\
a_{1,n} &= a_{1,n-1} \\
&= 1, \\
b_{0,n} &= b_{0,n-1} + \frac{1}{2}\left(\left(b_{1,n-1}-1\right)\sigma_\varphi + b_{2,n-1}\sigma_{g\varphi}\right)^2 + \frac{1}{2} b_{2,n-1}^2 \sigma_g^2 + \left(\left(b_{1,n-1}-1\right)\sigma_\varphi + b_{2,n-1}\sigma_{g\varphi} + b_{2,n-1}\sigma_g\right)\lambda, \\
b_{1,n} &= b_{1,n-1} \\
&= 1 + \xi, \\
b_{2,n} &= b_{2,n-1} \\
&= 1.
\end{aligned}
$$

To derive a tractable expression for the price-dividend ratio, recall that

$$\begin{aligned} SD_t &= \sum_{n=1}^{\infty} \exp\left(-y_t^{(n)} n\right) FD_t^{(n)} \\ &= \sum_{n=1}^{t_1-t-1} \exp\left(-y_t^{(n)} n + c_{0,n}\right) + \\ &\sum_{n=t_1-t}^{\infty} \exp\left(-y_t^{(n)} n + a_{0,n} + a_{1,n}\varphi_t\right) - \exp\left(-y_t^{(n)} n + b_{0,n} + b_{1,n}\varphi_t + b_{2,n} g_t\right). \end{aligned}$$

We consider a first order Taylor expansion of $\ln SD_t$ in $\Big(-y_t^{(n)} n + c_{0,n}, -y_t^{(n)} n + a_{0,n} + a_{1,n}\varphi_t, -y_t^{(n)} n + b_{0,n}$ - around $\left(-y_{t_0^-}^{(n)} n + n\mu^\star, \ln 2 - y_{t_0^-}^{(n)} n + n\mu^\star, -y_{t_0^-}^{(n)} n + n\mu^\star\right)$, which implies

$$\begin{aligned} \ln SD_t - \ln SD_{t_0^-} \simeq & -\sum_{n=1}^{\infty} \theta_{t_0^-}^{(n)} n \left(y_t^{(n)} - y_{t_0^-}^{(n)}\right) + \sum_{n=1}^{t_1-t-1} \theta_{t_0^-}^{(n)} \left(c_{0,n} - n\mu^\star\right) \\ & + \sum_{n=t_1-t}^{\infty} \left[\theta_{t_0^-}^{(n)} \left(h_{0,n} - n\mu^\star + h_{1,n}\varphi_t + h_{2,n} g_t\right)\right], \end{aligned}$$

where

$$\begin{aligned} SD_{t_0^-} &= \sum_{n=1}^{\infty} \exp\left(-y_{t_0^-}^{(n)} n + n\mu^\star\right), \\ \theta_{t_0^-}^{(n)} &= \frac{\exp\left(-y_{t_0^-}^{(n)} n + n\mu^\star\right)}{SD_{t_0^-}}, \end{aligned} \tag{13}$$

and $h_{0,n} = (2a_{0,n} - b_{0,n})$, $h_{1,n} = (2a_{1,n} - b_{1,n}) = 1 - \xi$, and $h_{2,n} = -b_{2,n} = -1$. Note that $\theta_{t_0^-}^{(n)}$ are weights that add to one across maturities. We notice that with $t_1 - t$ equal to, say, 3, we have[16]

$$\ln SD_t - \ln SD_{t_0^-} \simeq constant + (1-\xi)\varphi_t - g_t - \sum_{n=1}^{\infty} \theta_{t_0^-}^{(n)} n \left(y_t^{(n)} - y_{t_0^-}^{(n)}\right).$$

---

[16] Formally, we approximate $\sum_{n=t_1}^{\infty} \theta_{t_0^-}^{(n)} \simeq 1$.

This ultimately implies

$$\ln S_t - \ln S_{t_0^-} = constant - \xi \varphi_t - g_t - \sum_{n=1}^{\infty} \theta_{t_0^-}^{(n)} n \left(y_t^{(n)} - y_{t_0^-}^{(n)} \right).$$