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Sampling error and the joint estimation of imputation credit value and cash dividend value

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Abstract

The value of imputation credits can only be estimated jointly with the value of cash dividends. We show that random variation across samples leads to estimates of credit value that move in the opposite direction to estimates of cash value. Derivative prices suggest a value for credits of 0.01 to 0.20 (0.01 to 0.07 if cash is worth 0.94, and 0.13 to 0.20 if cash is worth 0.87). Ex-dividend prices suggest a value for credits of 0.23 to 0.46 (0.23 to 0.36 if cash is worth 0.85, and 0.33 to 0.46 if cash is worth 0.75).

Key words: Imputation credits; Cost of capital; Regression; Collinearity

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1. Introduction

Since dividend imputation was introduced to Australia 35 years ago, researchers and corporate finance practitioners have debated the extent to which imputation credits are incorporated into share prices. One reason for divergent opinions is that random variation in samples leads to estimates of the value of imputation credits moving in the opposite direction to estimates of the value of cash. This occurs because franking credits are only attached to dividends and presents an interpretation challenge even if collinearity metrics are at levels considered generally acceptable.

We illustrate this problem using simulation analysis. Then, we estimate the value of imputation credits across three tax regimes, accounting for the joint

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estimation of imputation credit value and cash dividend value. We rely upon two empirical datasets (derivative prices and ex-dividend prices) and present bootstrapped confidence intervals. The bootstrapped samples show the inverse relationship between estimated credit and cash values and allow us to make conditional statements on the value of credits. Derivative prices suggest a value for credits of 0.01 to 0.20 (0.01 to 0.07 if cash is worth 0.94, and 0.13 to 0.20 if cash is worth 0.87). Ex-dividend prices suggest a value for credits of 0.23 to 0.46 (0.23 to 0.36 if cash is worth 0.85, and 0.33 to 0.46 if cash is worth 0.75).

2. Literature review

2.1. Empirical evidence on the impact of imputation

Since the introduction of dividend imputation to Australia in 1987, researchers have attempted to measure its impact on share prices, investment decisions of portfolio managers, and corporate policy regarding capital structure and distributions to equity holders. The unresolved issue is how to incorporate imputation credits in valuation and cost of capital estimates. In this section we document the research that appears settled, and the research which remains contentious.

We know that imputation credits form an important component of portfolio selection. Pension funds and unit trusts hold above-market weight positions in stocks that pay franked dividends (Jun *et al*., 2011). Off-market share buybacks have become a popular mechanism for distributing franking credits, and investors are prepared to tender shares at substantial discounts to market prices to participate. Brown and Davis (2012) report that in most off-market buybacks, investors sell their shares back to the company at the maximum discount of 14 percent allowed by the Australian Taxation Office (ATO). Upon the announcement of an off-market buyback, there is abnormal trading volume amongst shares in which franking credits will form part of the distribution, consistent with shares being bought by investors who will receive the most cash benefit from the credits (Yong *et al*., 2014).

We also know that imputation credits affect corporate leverage. Subsequent to the introduction of dividend imputation, firms altered their capital structures towards relatively greater use of equity over debt (Twite, 2001). In addition, prior to imputation, firms' marginal tax rates and leverage were inversely related, consistent with capital structure theory in a classical tax system. However, the inverse relationship between a firm's marginal tax rate and leverage is not present following the introduction of imputation (Twite, 2001; Pattenden, 2006). This is consistent with managers responding to a reduction in the incremental tax benefit of debt over equity.

Finally, we know that imputation affects the decision as to whether a company conducts an on-market buyback or an off-market buyback. When a firm has a large franking account balance, there is a greater chance that it conducts an off-market buyback, rather than an on-market buyback (Brown and Norman, 2010); when a firm has a very large amount of surplus cash to distribute, the off-market buyback is the predominant way to distribute cash as opposed to paying a special dividend or conducting an on-market buyback (Coulton and Ruddock, 2011);[1] trading volume is abnormal upon the final announcement of an off-market buyback and in subsequent days as investors with low marginal tax rates attempt to increase their exposure to the distribution of franking credits (Yong *et al*., 2014); firms conducting on-market buybacks do so at the expense of ordinary dividends, but firms conducting off-market buybacks (in which the distribution of credits is larger and shares can be bought at a discounted price) are effectively distributing more imputation credits than they would otherwise (Brown *et al*., 2015); a company is more likely to institute a dividend reinvestment program the higher its franking percentage and subsequent to the July 2000 introduction of the cash rebate (Abraham *et al*., 2015); and dividends of Australian-listed corporations increase with Australian-paid taxes (which generate imputation credits) but decrease with foreign taxes (Akhtar, 2018).[2]

What is far from settled, however, is the relationship between imputation credits and stock prices. There is no consensus about how much different a company's stock price would be, contingent upon whether its dividends are accompanied by imputation credits. Recent estimates of the value of a distributed credit from dividend drop-off studies include 0.57 from Beggs and

[1]Coulton and Ruddock (2011) report that the average off-market buyback from 1993 to 2004 involved the distribution of $304 million compared to $50 million for regular dividends, $35 million for special dividends and $49 million for on-market buybacks. The sample contains 34 off-market buybacks only, so they do not occur often. But the off-market buybacks that do occur are very large.

[2]Davis (2016, p. 18) summarises the state of play as 'There is evidence that Australian listed companies generally have higher dividend payout ratios than comparable companies overseas. There have been a number of studies that demonstrate an increase in dividend payout ratios following the introduction of imputation such that Australian dividend payout ratios exceed those found overseas. Several other features of company financial behaviour follow from this, including: less use of on-market share repurchases; and greater use of dividend reinvestment schemes. Australian listed companies also exhibit less leverage than found overseas, and leverage declined following the introduction of imputation'.

Skeels (2006),[3],' 0.40 from Minney (2010),[4],7 0.35 from Cannavan *et al.* (2013),[5] and 0.34 from Vo *et al.* (2013).[6] Studies of security prices other than cum- and ex-dividend stock prices have generated estimates of franking credit values of 0.52 from Cummings and Frino (2008),[7] and 0 from Cannavan *et al.* (2004).[8]

These values, with the exception of that from the last study by Cannavan *et al.* (2004), have been estimated with respect to the *cash rebate* regime (in effect since 1 July 2000) that allows Australian resident investors to receive a cash rebate for imputation credits. The suite of estimates of imputation credit value from the *cash rebate* regime is illustrated in Figure 1. The figure also shows the

[3]Table 5, p. 247.

[4]Table 1, p. 31, with reference to the time period of 2001 to 2004. Minney (2010) reports a coefficient of 0.177. He states on the same page that, to obtain an estimate of what the market will pay to obtain a $1 franking credit, the coefficient needs to be divided by (corporate tax rate ÷ [1 – corporate tax rate]). Over the 9-year period analysed, the average corporate tax rate is 30.44 percent, with 1 year in which the corporate tax rate is 34 percent and 8 years in which the corporate tax rate is 30 percent. The estimated value of imputation credits is 0.177 ÷ (0.3044 ÷ [1 – 0.3044]) = 0.177 ÷ 0.4377 = 0.4044.

[5]Table 3, p. 20, with reference to model 4. In the 2013 paper, we update the analysis presented in an earlier paper (Costello *et al.*, 2011) that was relied on by the Australian Competition Tribunal in *Application by Energex Limited (Gamma) (No 5) [2011] ACompT 9 (12 May 2011)*. We also perform additional robustness tests. The particular coefficient estimate of 0.35 from Table 4, p. 20, is not the only information relied on to reach a conclusion that the estimated value of credits is 0.35. But, for comparison purposes, we focus on the most reliable estimate of credit value from all estimates reported in each study. Results are updated using data to 2016 by Cannavan and Gray (2017).

[6]The researchers reach a conclusion that if a point estimate for the value of a distributed credit is required, then it should be 0.45 based on an average value across different robust regression models (pp. 29–30). The figure of 0.45 is estimated by ignoring any movement in market prices in estimating the expected change in share price on the ex-dividend date. This research paper is the only study from the list above that assumes that the expected stock return on the ex-dividend date is independent of changes in other share prices. We reported the estimate of 0.34, which is the corresponding estimate to 0.45 for the value of a distributed credit under the assumption that the expected stock return is equal to the market return.

[7]Table 2, Panel B, p. 400.

[8]Table 3, Panel E, p. 189.

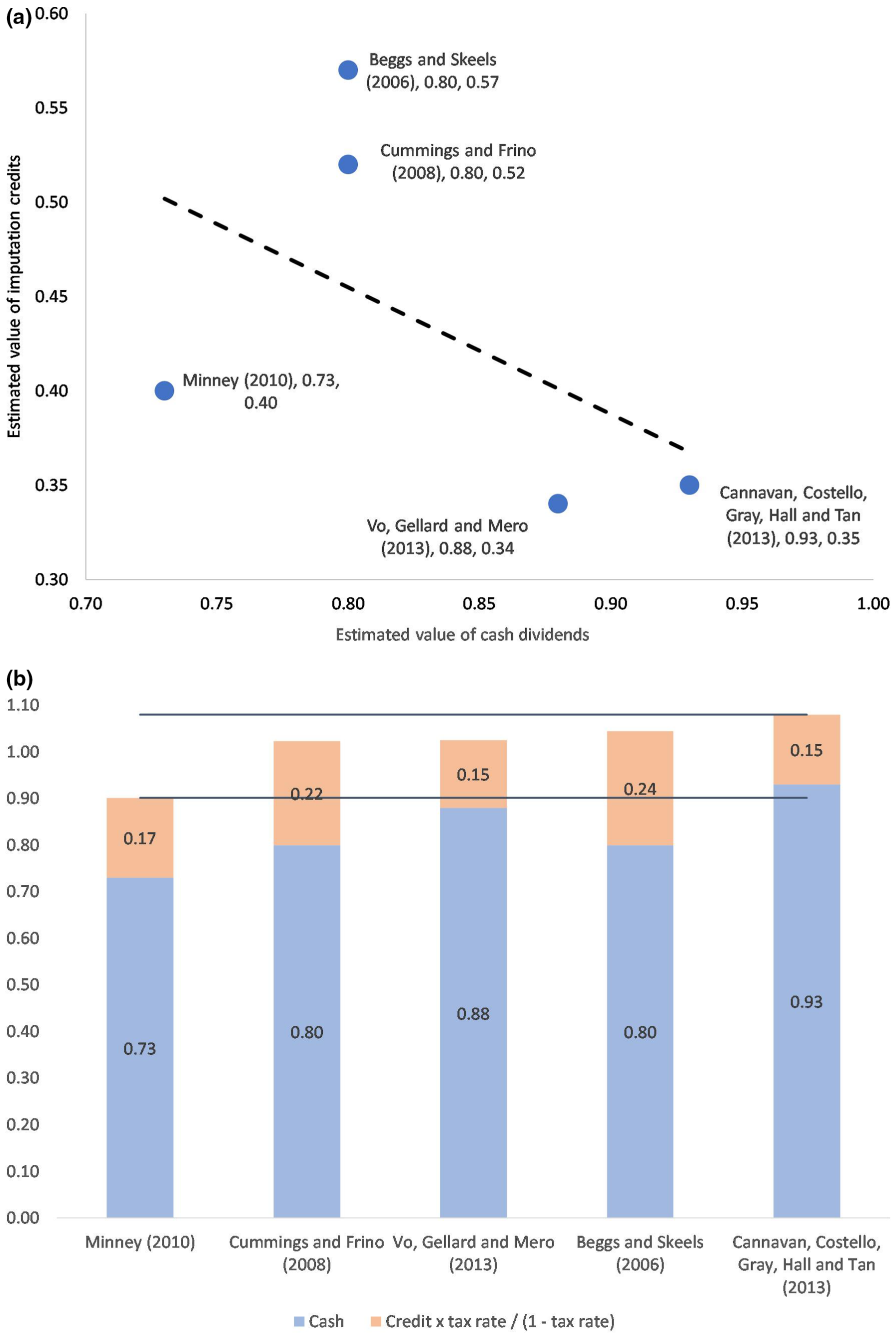

Figure 1 Prior estimates of the value of cash dividends and imputation credits in the cash rebate period. Panel a: Inverse relationship between estimates of the value of cash and the value of credits. Panel b: Estimates of the value of a fully franked dividend.

estimated value of cash dividends and the estimated value of a fully franked dividend package. There are two important implications.

First, there is an inverse relationship between estimates of cash value and credit value. The two papers with the highest cash value estimates have the lowest credit value estimates (Cannavan *et al.*, 2013; Vo *et al.*, 2013), and the two papers with the lowest cash value estimates have the highest credit value estimates (Beggs and Skeels, 2006; Cummings and Frino, 2008).[9] The range for the market value of cash is 0.73 to 0.88.[10]

Second, despite variation across studies in the estimated value of imputation credits, there is little variation in the implied value of a fully franked dividend package. Suppose we assign the following notation. Delta (δ) is the estimated value of cash; theta (θ) is the estimated value of an imputation credit; and tao (τ) is the corporate tax rate. At a corporate tax rate of 30 percent, the implied value of a fully franked dividend can be computed as $\delta + \theta \times (\tau \div [1 - \tau]) = \delta + \theta \times (0.30 \div [1 - 0.30]) = \delta + \theta \times 0.43$. The range for an estimated value of a fully franked dividend package across the four papers is just 1.02 to 1.08.[11] The implication of this narrow range for the value of a fully franked dividend package is that variation in the estimated value for imputation credits is offset by variation in the estimated value for cash dividends.

[9]The remaining paper by Minney (2010) has the median estimated value for credits of 0.40 and an estimated value for cash dividends of 0.73, the lowest cash value estimate from the five papers. However, as mentioned previously, we estimated the cash value from the regression intercept and the average dividend yield for the All Ordinaries Index over the sample period.

[10]The specific point estimates for the estimated value of credits and cash are 0.57 and 0.80 (Beggs and Skeels, 2006); 0.52 and 0.80 (Cummings and Frino, 2008); 0.40 and 0.73 (Minney, 2010); 0.35 and 0.93, Cannavan *et al.* (2013); and 0.34 and 0.88 (Vo *et al.*, 2013). With respect to the paper by Minney (2010), we estimated the value of cash dividends on the following basis. The model used by Minney (2010) implies that the cash value equals 1 – (regression intercept ÷ dividend yield). The dividend yield for the sample is not reported, so we computed the average daily dividend yield on the All Ordinaries Index over the sample period, which was equivalent to 1.85 percent on a semi-annual basis. The estimated value for cash dividends equals $1 - (0.005 \div 0.0185) = 1 - 0.27 = 0.73$.

[11]The computations are as follows: for Beggs and Skeels (2006), we have $0.80 + 0.57 \times 0.43 = 1.04$; for Cummings and Frino (2008), we have $0.80 + 0.52 \times 0.43 = 1.02$; for Cannavan *et al.* (2013), we have $0.93 + 0.35 \times 0.43 = 1.05$; and for Vo *et al.* (2013), we have $0.88 + 0.34 \times 0.43 = 1.03$.

2.2. Interpretation by regulators

Regulators have a particular interest in the value of imputation credits because this value forms part of either a regulated rate of return or an allowance for tax in setting regulated prices.[12] At present, estimates for the value of a distributed credit include 0.45 from the Economic Regulation Authority of Western Australia (ERA, 2013a, 2013b);[13] and 0.35 from the Independent Pricing and Regulatory Tribunal of New South Wales (IPART, 2012).[14]

In other jurisdictions (Queensland,[15] South Australia,[16] Tasmania,[17] and at the national level[18]), the regulator either makes an estimate of the proportion of imputation credits that are redeemed by investors (the *redemption rate*) or sets regulated prices based on an aggregation of evidence relating to the redemption rate and the market value of credits.[19] So, in jurisdictions other than WA or

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[12]For a summary of one approach regulators use to account for imputation in setting the regulated revenue stream, see Gray (2016).

[13]The ERA considers that the value of a distributed imputation credit lies within a range of 0.35 to 0.55 (ERA, 2013a, para. 158, p. 31). However, its best estimate of the value of a distributed credit is the midpoint figure of this range (ERA, 2013b, appendix 30, para. 52, p. 220)

[14]P. 8.

[15]The Queensland Competition Authority (QCA) relies on a redemption rate estimate of 0.56 as the proportion of Australian-listed shares owned by Australian resident investors (QCA, 2014, sub-section 5.5, p. 29). The QCA does not rely on a market value estimate of imputation.

[16]The Essential Services Commission of South Australia (ESCOSA, 2012, sub-section 7.3, p. 49) states that the parameter ‘theta’ (which it refers to as the utilisation rate) lies within a range of 0.35 to 0.81, in which the lower bound is an estimate from a dividend drop-off study (Costello *et al*., 2011) and the upper bound is an estimate from a redemption rate study (Handley and Maheswaran, 2008).

[17]The Office of the Tasmanian Economic Regulator (OTTER, 2012, sub-section 4.3.2.1, p. 58 and table 4.9) defines ‘gamma’ as “the proportion of imputation credits that can be utilised by shareholders” and uses an estimate of gamma equal to 0.50.

[18]The Australian Energy Regulator (AER, 2013) discusses evidence of the market value of a distributed credit and the redemption of credits in appendix H and considers both sources of evidence. In making estimates of the market risk premium from historical returns and incorporating an adjustment to returns to account for a benefit from imputation credits, the AER gives a weight of 0.70 to a distributed credit (i.e., ‘theta’ in the computations is set equal to 0.70; sub-section B.1.1, p. 27). But the AER makes clear in its discussion in appendix H that this is not an estimate of the market value of a distributed credit.

[19]The ERA (2015) also sets regulated prices on the basis of an aggregation of evidence relating to the redemption rate and the market value of credits, but has conducted its own analysis on the specific issue of the market value of a distributed credit.

NSW, the assumed market value of a distributed credit is not specified. In the two jurisdictions for which we have a specific estimate of the market value of a distributed credit, we have market value estimates relative to face value of 0.45 (WA) and 0.35 (NSW). These market value estimates lie within the range of point estimates (0.34 to 0.57) from the empirical studies referred to above.

2.3. Reconciling the evidence

The first suite of empirical evidence mentioned above, from the decisions of portfolio managers and corporate managers, indicates that executives recognise the cash-flow benefits of imputation credits to Australian investors and this implies that the market value of imputation credits should be substantially less than one. Consider the counterfactual – if ordinary share prices reflected the full value of imputation credits then:

- portfolio managers would have no reason to take overweight positions in stocks paying franked dividends (investors would be indifferent between buying a high-priced share to receive imputation credits or buying a low-priced share that did not distribute credits);
- companies would not have lowered their leverage following the introduction of imputation, and we would observe an inverse relationship between companies' marginal tax rates and leverage; and
- companies would have no incentive to engage in off-market buybacks (the value-maximising strategy would be to increase the dividend on ordinary shares and then fund operations by regular issues of new shares at the high price that reflects the value of credits).

Further evidence consistent with share prices reflecting a value for imputation credits less than one is presented by Siau *et al.* (2015). If share prices incorporate a positive value for imputation credits, we should expect stocks with higher imputation credit yields to trade on higher price-to-earnings ratios. Yet, for portfolios with the same dividend yield, the researchers do not find a relation between imputation credit yield and the price-to-earnings ratio.[20] After controlling for variables that proxy for risk and growth (beta, market capitalisation, market-to-book ratio and projected earnings growth), Siau *et al.* (2015) find a positive relationship between imputation credit yield and earnings

[20]Stocks in the lowest quintile of imputation credit yield have an average imputation credit yield of 0.8 percent and an average price-to-earnings ratio of 14.4. Stocks in the highest quintile of imputation credit yield have an average imputation credit yield of 2.3 percent and an average price-to-earnings ratio of 14.7 (Siau *et al.*, 2015, table 4, pp. 24–25).

yield (i.e., stocks with higher imputation yields trade on lower price-to-earnings ratios).[21] Also, no evidence suggests that stocks that distribute more imputation credits, on average, have earned relatively lower returns from dividends and capital gains since dividend imputation was introduced in 1987 (Lajbcygier and Wheatley, 2012), although the large standard errors from returns-based evidence limits the implications that can be drawn from this analysis.[22]

Thus, the empirical evidence on the market value of imputation credits boils down to the following conflict. Share prices do not reflect the full value of imputation credits. This provides the incentive for portfolio managers to take overweight positions in stocks paying franked dividends, for companies to have lower leverage than would occur in a classical tax system and for companies to distribute credits in off-market buybacks. Price-to-earnings ratios do not appear to bear any relation to the amount of credits distributed. Yet, according to studies of ex-dividend prices and futures contract prices in the current tax regime, imputation credits have a material, positive value (point estimates across studies of 0.34 to 0.57).

3. Joint estimation of cash dividends and imputation credits

In this paper we make the point that a study on the estimation of imputation credit value necessarily generates an estimate of the value of cash, and both estimates need to be taken into account in making a practical inference. How to interpret cash value estimates within the range of 0.73 to 0.88 depends critically on the reason these values are less than one. There are three possibilities.

First, it could be the case that the estimated value of cash dividends is independent of the value of imputation credits. This is the implicit interpretation of the ERA and IPART. Those regulators interpret the evidence on credit value (0.34 to 0.57) but in setting prices for regulated entities assume cash is fully-valued.

[21]Table 5, pp. 27-28.

[22]A final study to note is that of Jun and Partington (2014), who examine the ex-dividend trading of stocks trading in Australia and in the United States as American Depository Receipts (ADRs). For a period, the ADRs traded cum-dividend and the Australian-listed shares traded ex-dividend, so the price differences can be used to estimate the market value of the dividend and the associated franking credits. Cash dividends are valued at about 40 cents on the dollar, and imputation credits have no value (table 4, panel B, fourth row). In contrast, when just considering Australian-listed shares in a dividend drop-off study, cash is worth about 92 cents in the dollar and credits are worth 25 percent of face value (table 5, panel B, final row). Thus, we have some evidence that the U.S. and Australian markets are not entirely integrated so dividends are priced differently. The sample period is from 1992 to 2009, so we do not include the paper in our comparison of papers that exclusively focuses on the cash rebate period.

Second, it could be the case that sampling error leads to estimates for cash value and credit value moving in opposite directions, relative to the true value of cash and credits. This is our conjecture.

A third possibility is that empirical analysis leads to a downward bias in the estimated value of cash *and* a downward bias in the estimated value of credits. In this situation, something about the data or the research method leads to both parameter estimates being understated, and so both estimates need to be 'grossed-up' to reflect the true values for cash and credits.[23]

Thus, we have the following research question. *In repeated samples, do we expect the empirical estimates for cash value and credit value to be independent (the first possibility), negatively correlated (the second possibility) or positively correlated (the third possibility)?*

This issue arises because we can never observe the price of an imputation credit separate from the price of a dividend. As noted by Ainsworth *et al.* (2016, p. 45), 'The most substantive problem relates to the fact that dividends and imputation credits arrive together as a package. This greatly hampers the ability of researchers to confidently tease out how imputation impacts prices relative to other influences. It is known as the "allocation problem" and refers to the identification issues that arise from the need to disentangle two components that are highly correlated with a problematic distribution (most dividends are either fully franked or unfranked)'.

In prior work this issue has been addressed as a collinearity issue, given that we often have two variables on the right hand side of an equation that are positively correlated (dividends and imputation credits, given that the majority of dividends are fully franked). But we document that even at generally-accepted metrics for low correlation, there remains a joint estimation issue.

Estimates of the value of imputation credits rely on variations to the following general equation:

Price of a security that entitles the holder to a dividend = Price of a security that does not entitle the holder to a dividend + $\delta \times$ Cash dividend + $\theta \times$ [Cash dividend $\times \tau \div (1 - \tau) \times$ Franking percentage].

This general equation means that there is positive correlation between the two independent variables. At correlations of high magnitude, noise in the data can lead to coefficients with counterintuitive signs and large standard errors. Thus, a standard approach amongst researchers is to decide whether they can sensibly interpret coefficients according to cutoffs related to three metrics: the correlation itself, the variance inflation factor, or a condition index.

For instance, a common interpretation of the condition index of Belsley *et al.* (1980) is that a value between 5 and 10 suggests weak dependencies between variables and a value between 30 and 100 suggests a moderate to strong collinearity problem. As an example, Jun *et al.*, 2011, p. 222) rely on a

[23]As an example of this interpretation, see AER (2013, sub-section H.6.4, tables H.9 and H.10, pp. 176–177).

condition index of 30 as a cutoff for interpretation, stating that 'The multicollinearity problem was mitigated by dropping $\text{DUMMY}_{IfPaying}$ out of the regressions which reduced the condition index below 30'. The researchers go on to interpret the regression coefficients. In other situations, researchers examine the standard errors and associated confidence intervals and assume that collinearity is not an issue when standard errors are sufficiently small. As an example, Cummings and Frino (2008, p. 396) state that 'Although the variables $Cash_t$ and $Franking_t$ are also highly collinear (correlation of 0.877), reasonably narrow confidence intervals for the parameter estimates are obtained for the entire sample spanning four years'.

Using simulated data and bootstrapped empirical analysis, we demonstrate that there is a material inverse relationship between estimates for the value of cash and the value of credits, even when condition indices and correlations fall within generally-accepted bounds. There is a joint estimation issue even when there is only one independent variable, because there will necessarily be an estimated value for cash (either from comparison of fully franked versus unfranked dividends, or with reference to an intercept). The implication is that researchers and regulators need to be cautious about interpreting variation in credit value estimates to fundamental issues (like tax changes, which we discuss) when much variation in credit value estimates is driven by random sample variation.

4. Simulation

4.1. Motivation

The purpose of the simulation analysis is to illustrate the potential variation in estimates of credit value and cash value across different samples simply due to random variation. In our empirical analysis we perform repeated samples analysis to form confidence intervals that take account of joint estimation of credit value and cash value.

4.2. Independent observations

We illustrate the likely inverse relationship between credit value estimates and cash value estimates using a simulated, representative dataset. For ease of exposition, the example is framed with reference to a dividend drop-off study. However, the conclusions apply equally to a simultaneous pricing study, because we do not incorporate any microstructure effects associated with trading on the cum- and ex-dividend dates. The parameter estimates assumed in the simulation are consistent with our dividend drop-off sample in terms of the proportion of franked, unfranked and partially franked dividends, the dividend yield and the noise in estimated share price changes on the ex-dividend date.

There are 5,000 observations of a cum-dividend stock price and an ex-dividend stock price. There are 3,500 fully franked dividends, 750 unfranked dividends and 750 partially franked dividends.[24] The partially franked dividends have franking from 0.13 percent to 99.87 percent in equal increments. The cum-dividend price for all stocks is \$1.0000, and the corporate tax rate (τ) is 30 percent.

The dividend amount and the ex-dividend price are randomly generated by the following process: the dividend is drawn from a normal distribution with mean of \$0.0200 and standard deviation of \$0.0050, but the lower bound is constrained at \$0.0025.[25] This is equivalent to an annual dividend yield of 0.5 percent for the lowest yield stock, assuming semi-annual dividend payments.

The ex-dividend price is formed after assuming the market values of cash dividends and imputation credits. The mean reduction in share price on the ex-dividend date is computed as cash dividend value (δ) × dividend + imputation credit value (θ) × imputation credit + noise (ε). The noise component of the price change is drawn from a normal distribution with mean of 0 and standard deviation of \$0.0200.[26] The random draw of the dividend amount and ex-dividend price can be expressed by the following equation in which η_1 and η_2 are random draws from a normal distribution:

$$\begin{aligned}
&\textit{Cum dividend price} - \textit{Ex dividend price} \\
&= \textit{Value of cash dividend} \times \textit{Cash dividend} + \textit{Value of credit} \times \textit{Credit} \\
&+\textit{Noise} = \delta \times [Max(0.0200 + \eta_1 \times 0.0050), 0.0025] + \theta \\
&\times [Max(0.0200 + \eta_1 \times 0.0050), 0.0025] \times \frac{0.30}{1 - 0.30} \\
&\times \%\textit{Franked} + 0.0200 \times \eta_2
\end{aligned}$$

[24]In our ex-dividend sample of 12,975 observations, the distribution of franking attached to dividends is 75 per fully franked, 10 percent partially franked and 15 percent unfranked. In our derivatives sample, 23,293 observations have an ex-dividend date prior to the expiration of the derivative and the franking credit distribution is 73 percent franked, 15 percent partially franked and 12 percent unfranked.

[25]In our ex-dividend sample the dividend yield has an average of 2.40 percent and standard deviation of 1.29 percent. In our derivatives sample the observations with ex-dividend dates prior to the expiration of the derivative have dividend yield with an average of 1.76 percent and standard deviation of 0.92 percent.

[26]In our ex-dividend sample regressions the standard deviation of residuals is 2.41 percent. In our derivatives sample regressions the standard deviation of residuals is 0.46 percent.

We compile 1,000 samples of ex-dividend prices, cash dividends and imputation credits and then perform an ordinary least squares (OLS) regression on each sample. Doing so allows us to generate a distribution of coefficients which are estimates of the value of cash dividends ($\hat{\delta}$) and imputation credits ($\hat{\theta}$). In the following regression equation, the subscript i represents ex-dividend event i, and, in our first illustration, all observations are independent:

$$\frac{Cum\,div\,price_i - Ex\,div\,price_i}{Cum\,div\,price_i} = \alpha + \hat{\delta} \times \frac{Cash\,dividend_i}{Cum\,div\,price_i} + \hat{\theta} \times \frac{Cash\,dividend_i}{Cum\,div\,price_i} \times \frac{0.30}{1-0.30} \times \%Franked_i + \epsilon_i.$$

We present the distribution of parameter estimates for a case in which the true value for cash dividends (δ) is 1.00, and the true value for imputation credits (θ) is 0.20. Figure 2 illustrates the joint distribution of 1,000 regression estimates for the value of cash and the value of imputation credits. The two parameter estimates are inversely related:

- when a sample of data leads to a high estimate for the value of cash (i.e., $\hat{\delta}$ is greater than 1.00), the average estimate for the value of imputation credits ($\hat{\theta}$) is below the true value of 0.20 (on average, $\hat{\theta}$ is 0.18); and
- when a sample of data leads to an estimate for the value of cash less than or equal to 1.00, the average estimated value for credits is 0.22.

The relationship between the estimated value for credits and the estimated value for cash can be given by the equation *Credit value estimate* = 0.71–0.51 × *Cash value estimate*. The correlation between the coefficient estimates on dividend yield and imputation credit yield from repeated samples is –0.38. On average, the correlation between the independent variables is 0.44, the variance inflation factor is 1.2 and the condition index is 10.

In Table 1 we summarise the distribution of parameter estimates. In 95 percent of outcomes, the estimated value for credits lies within the range of 0.04 to 0.36, the estimated value for cash lies within the range of 0.88 to 1.12 and the estimated value for a fully franked dividend package lies within the range of 0.97 to 1.20.[27] The implication is that a sample of data could feasibly generate an estimated value for credits as low as 0.04 or as high as 0.36 entirely due to noise in the underlying data. But high estimates for credit value will be associated with low estimates for cash value. The inverse relationship between estimated credit value and cash value occurs even though the typical metrics used to test collinearity are below acceptable commonly-accepted thresholds.

[27]The value of a fully franked dividend package is computed as estimated cash value plus the estimated credit value times 0.30 ÷ (1 – 0.30).

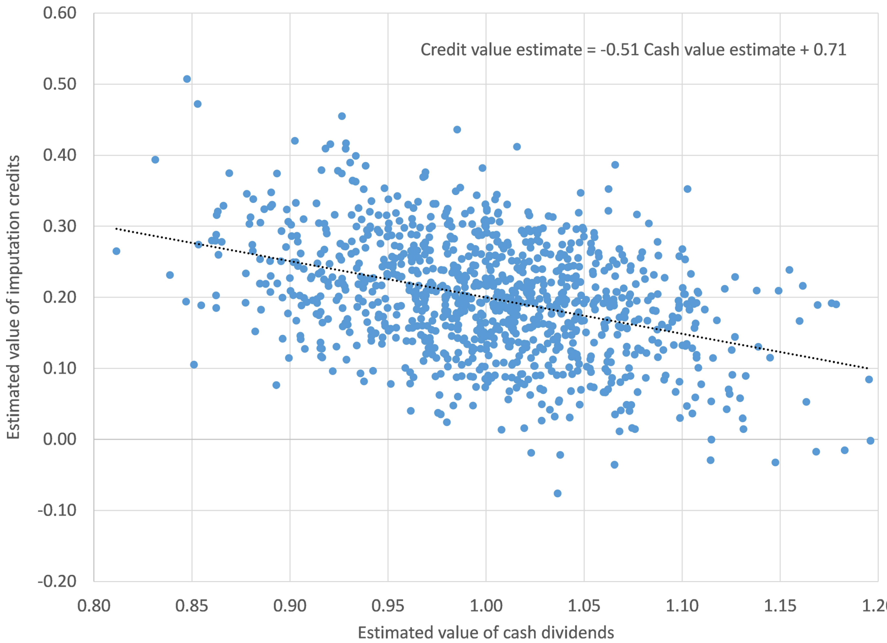

Figure 2 Coefficient estimates from repeated samples with independent observations.The figure summarises the results of a simulation analysis. We randomly generated 1,000 samples of 5,000 ex-dividend events under the assumption that the percentage share price change is equal to the cash dividend yield + 0.20 × franking credit yield + noise. We regressed percentage ex-dividend price changes on cash dividend yield and franking credit yield to compile 5,000 estimates on an intercept, estimated value for cash and estimated value for credits. The figure presents results under the assumption that each observation is independent. Assumptions underpinning franking, dividend yield and noise are presented in Section 4.

In this first illustration, sample observations are independent so the standard errors from OLS regression are unbiased. The standard deviation of parameter estimates represents the true standard error of the coefficient estimates. For the case in which all observations are independent, the standard deviation of coefficient estimates (0.12) is equal to the average standard error from the regressions (0.12).

4.3. Dependence across firms

Now suppose we introduce dependence across firms. Each firm now contributes five observations to a dataset that still has 5,000 observations, so we have 1,000 firms × 5 observations per firm. There remains one ex-dividend event for each pair of cum- and ex-dividend prices. We assume that some firms consistently pay high dividends and some firms consistently pay low dividends and this characteristic is persistent. Thus, we assume that each firm has the

Table 1
Coefficient estimates from repeated samples in simulated data

	Mean coefficient estimate	Standard deviation of coefficient estimate	Mean of standard error	95% conf int
Observations are independent				
Intercept	0.00	0.12	0.12	−0.19 to 0.19
Cash estimate	1.00	0.06	0.06	0.90 to 1.10
Credit estimate	0.20	0.08	0.08	0.07 to 0.33
Fully franked dividend	1.09	0.06	0.06	0.99 to 1.18
Dependence across firms				
Intercept	0.00	0.20	0.12	−0.35 to 0.33
Cash estimate	1.00	0.11	0.06	0.82 to 1.18
Credit estimate	0.20	0.15	0.08	−0.03 to 0.44
Fully franked dividend	1.09	0.10	0.06	0.93 to 1.25
Dependence across firms and events				
Intercept	0.00	0.37	0.12	−0.57 to 0.60
Cash estimate	1.00	0.20	0.06	0.67 to 1.33
Credit estimate	0.20	0.27	0.08	−0.23 to 0.65
Fully franked dividend	1.09	0.18	0.06	0.80 to 1.37

The table summarises the results of a simulation analysis. We randomly generated 1,000 samples of 5,000 ex-dividend events under the assumption that the percentage share price change is equal to the cash dividend yield + 0.20 × franking credit yield + noise. We regressed percentage ex-dividend price changes on cash dividend yield and franking credit yield to compile 5,000 estimates on an intercept, estimated value for cash and estimated value for credits. The upper section presents results under the assumption that each observation is independent. The middle section presents results under the assumption that there are 1,000 firms and each firm experiences five ex-dividend events. There is a noise term per firm and a noise term per event, but overall noise is held constant. The lower section presents results under the assumption that there are 200 firms, five events per firm and five trades per event (analogous to our derivatives sample). Assumptions underpinning franking, dividend yield and noise are presented in Section 4.

same randomly generated dividend yield for all five observations, and each firm's dividend has the same franking percentage for all five dividends.

Then we introduce a firm-specific component to the error term. Recall that noise in the ex-dividend price was normally distributed with mean of zero and standard deviation of \$0.0200. Now, we split the noise in the ex-dividend price into two components of equal magnitude. There is a firm-specific component of noise with mean of zero and standard deviation of \$0.0141, and a random component of noise with mean of zero and standard deviation of \$0.0141. The firm-specific component of noise and the random component of noise are uncorrelated. This means that the total noise in the ex-dividend price remains the same as that in the independent dataset (standard deviation of \$0.0200), but there is persistence in the mispricing of five dividend events for the same firm.

The second row of data in Table 1 presents summary statistics for a simulation that accounts for dependence across firms. The standard deviation of the parameter estimates has increased to 0.11 for the value of cash, 0.15 for the value of imputation credits, and 0.10 for the value of a fully franked dividend. We can now see divergence between the average standard error from an OLS regression and the standard deviation of coefficient estimates from repeated samples. With respect to the estimated value of credits, the true standard errors are 70 percent above the standard errors implied by OLS regression.

With dependence in errors across firms, we also observe a stronger inverse relationship between the estimated value for cash dividends and the estimated value for imputation credits (Figure 3). The relationship between the two parameter estimates is now summarised by the equation: *Credit value estimate* = 0.79–0.59 × *Cash value estimate*. For samples in which the estimated value for cash is less than the true value of 1, on average, the estimated value for credits is 0.26; and for samples in which the estimated value for cash is more than the true value of 1, on average, the estimated value for credits is 0.15.

4.4. Dependence across firms and events

Finally, consider dependence in errors associated with each ex-dividend event. Suppose the sample of 5,000 observations comprises 200 stocks, each stock is associated with five ex-dividend events and five trades are associated with each event. (Recall that while we use the term ‘ex-dividend event’, this can be generalised to the case in which there are five trades per event, as in our derivatives sample in which we could observe multiple simultaneous trades of a derivative and an ordinary share for a stock with the same upcoming dividend. The simultaneous trading of a derivative and share price is analogous to the cum- and ex-dividend stock prices.). The total pricing error is equally allocated to a firm-specific component, an event component and a random component. The error components are uncorrelated, and each component of error has a standard deviation of $0.0115. So, on average, the total standard deviation of errors remains $0.0200.

With increased dependence in error terms across observations, we see a further material increase in the true standard errors from repeated samples. The standard deviation of the parameter estimates has increased to 0.20 for the value of cash, 0.27 for the value of imputation credits and 0.18 for the value of a fully franked dividend package. This means that the true standard errors are three times what would be computed under the assumption of independence. Figure 4 illustrates the increased dispersion of parameter estimates as dependence increases and a further increase in the inverse relationship between the estimates for cash and imputation credit values. Now the equation is: *Credit value estimate* = 0.82–0.62 × *Cash value estimate*.

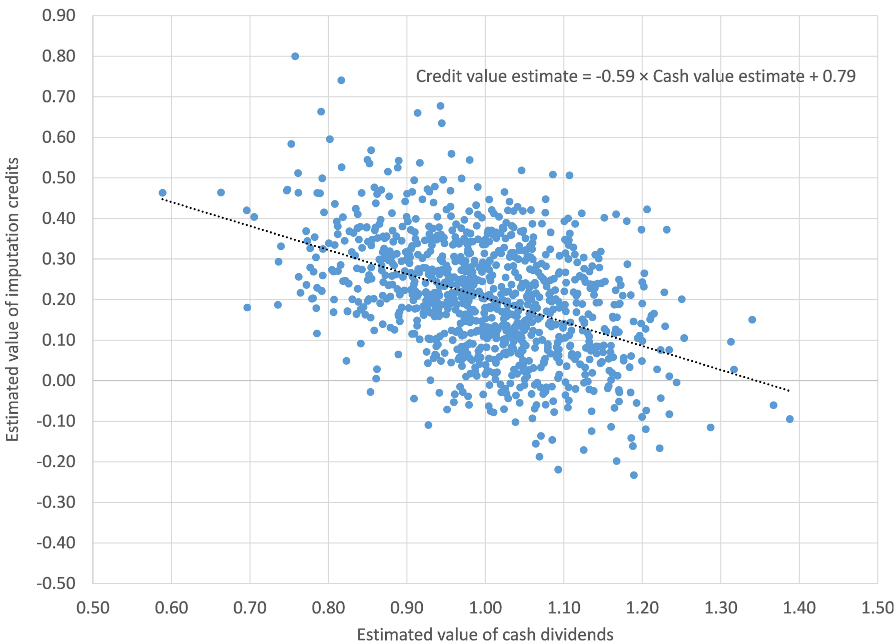

Figure 3 Coefficient estimates from repeated samples with dependence across firms.The figure summarises the results of a simulation analysis. We randomly generated 1,000 samples of 5,000 ex-dividend events under the assumption that the percentage share price change is equal to the cash dividend yield + 0.20 × franking credit yield + noise. We regressed percentage ex-dividend price changes on cash dividend yield and franking credit yield to compile 5,000 estimates on an intercept, estimated value for cash and estimated value for credits. The figure presents results under the assumption that there are 1,000 firms and each firm experiences five ex-dividend events. There is a noise term per firm and a noise term per event, but overall noise is held constant. Assumptions underpinning franking, dividend yield and noise are presented in Section 4.

4.5. *Sensitivity analysis*

The implications of our simulation analysis are there is an inverse relationship between the estimated value for cash dividends and credits; this inverse relationship increases with reduced independence of observations; and a lack of independence amongst observations markedly increases the true standard error.

These issues remain even if we run the regressions with only one variable on the right-hand side. Suppose the dependent variable is computed as the drop-off ratio (change in share price, scaled by dividend), the independent variable takes on a value of one for fully franked dividends and zero for unfranked dividends, and we remove partially franked dividends. In this specification the intercept is the estimated value for cash and the coefficient on the independent variable represents the increased value associated with franking

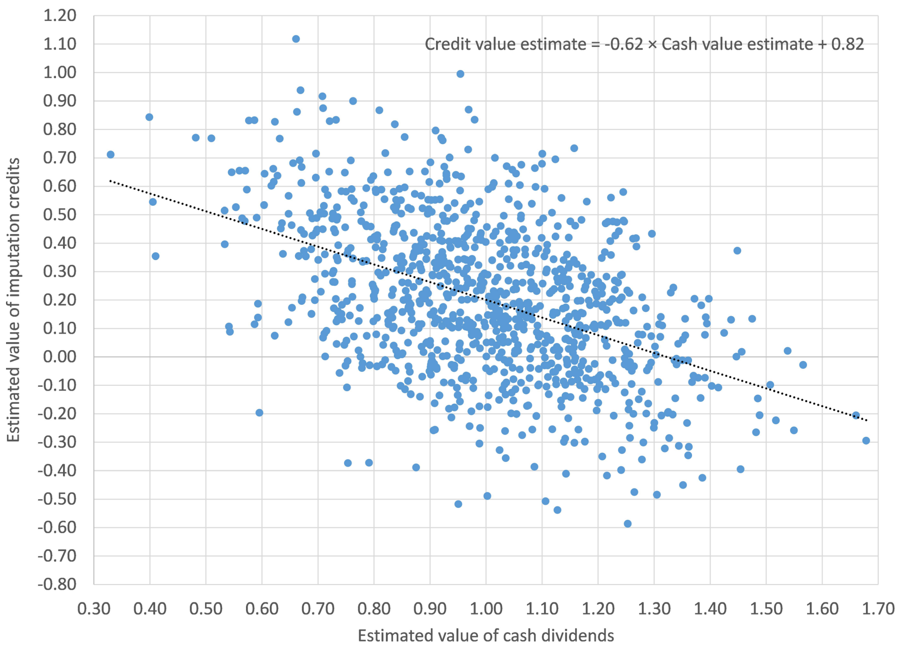

Figure 4 Coefficient estimates from repeated samples with dependence across firms and events.The figure summarises the results of a simulation analysis. We randomly generated 1,000 samples of 5,000 ex-dividend events under the assumption that the percentage share price change is equal to the cash dividend yield + 0.20 × franking credit yield + noise. We regressed percentage ex-dividend price changes on cash dividend yield and franking credit yield to compile 5,000 estimates on an intercept, estimated value for cash and estimated value for credits. The figure presents results under the assumption that there are 200 firms, five events per firm and five trades per event (analogous to our derivatives sample). Assumptions underpinning franking, dividend yield and noise are presented in Section 4.

(the value of an imputation credit is the coefficient on the franked dividend dummy × 0.3 ÷ (1 – 0.30)). For independent observations, the standard deviations across coefficient estimates are 0.04 for cash, 0.11 for credits and 0.02 for a fully franked dividend. Importantly, the relationship between estimated values for cash and credits can be expressed as: *Credit value estimate* = 0.47–0.43 × *Cash value estimate*. and the correlation between the estimated value for cash and credits is –0.92. This is equivalent to comparing average drop-off ratios for franked and unfranked dividends, so splitting the sample into different pools does not solve the joint estimation issue. In short, the inverse relationship between credit value estimates and cash value estimates occurs because credits are attached to dividends and cannot be addressed merely by consideration of correlation between two independent variables.

Our simulation analysis is designed to be broadly representative of an ex-dividend pricing study (5,000 observations; dividend yield = 2 percent; 70

percent fully franked, 15 percent partially franked, 15 percent unfranked; aggregate noise with standard deviation of 2 percent). The simulation in which there was 1,000 firms and five events per firm is analogous to an ex-dividend sample (one trade per firm per ex-dividend event); and the simulation in which there were 200 firms, five events per firm and five trades per event is analogous to a derivatives sample (in which there can be multiple trades per firm per event). The simulation analysis is designed to hold sample size constant and total noise constant as independence decreases.

However, it is worthwhile documenting what happens if we calibrate the simulation to our specific samples. In our ex-dividend sample, we have 961 firms and 12,975 observations (14 ex-dividend events per firm) with average dividend yield of 2.40 percent, standard deviation of dividend yield of 1.29 percent, and a standard error from our regressions of 2.41 percent. We have 75 percent fully franked dividends, 10 percent partially franked dividends and 15 percent unfranked dividends. If we use these assumptions in the simulation (breaking down the noise term into two uncorrelated parts of 1.70 percent) we have the following results. The standard errors are 0.06 for cash value, 0.13 for credit value and 0.05 for the value of a fully franked dividend. The relationship between credit value estimates and cash value estimates is *Credit value estimate* = 1.56–1.36 × *Cash value estimate* and the correlation between cash value estimates and credit value estimates across samples is –0.69.

In our derivatives sample we have 117 firms, 1,268 firm/ex-dividend event combinations and 23,939 observations in which there is an ex-dividend event prior to the expiration of the dividend (11 events per firm and 18 trades per firm per event). The average dividend yield is 1.76 percent, the standard deviation of dividend yield is 0.92 percent, and the standard deviation of residuals from our regressions is 0.46 percent. We have 73 percent franked dividends, 15 percent partially franked dividends and 12 percent unfranked dividends. If we use these assumptions in the simulation (breaking down the noise term into three uncorrelated parts of 0.26 percent) we have the following results. The standard errors are 0.03 for cash value, 0.08 for credit value and 0.02 for the value of a fully franked dividend package. The relationship between credit value estimates and cash value estimates is *Credit value estimate* = 1.90–1.70 × *Cash value estimate* and the correlation between cash value estimates and credit value estimates is –0.77.

5. Empirical method

5.1. Regression model

We perform analysis on two datasets: prices of individual share futures (ISFs) and low exercise price options (LEPOs) (the derivatives dataset), and ex-dividend share prices (the ex-dividend dataset). The regression model we use on both datasets is in the same format. The dependent variable is a measure of the percentage difference in the prices of two securities (for the derivatives dataset it is the percentage difference in the ordinary share prices and the derivative price; for the ex-dividend dataset it is the percentage difference in cum- and ex-dividend prices). The independent variables are dividend yield, and franking credit yield in three tax regimes (franking credit yield interacted with an indicator variable for each regime). The coefficient on the dividend yield is an estimate of the value of cash dividends; and the coefficients on the franking credit yields are estimates of the value of credits in each tax regime.

From Cannavan *et al.* (2004), we rely on the theoretical relationship between stock prices, and the prices of ISFs and LEPOs. We have one security (shares) that entitles the holder to the next dividend payment and another security (ISFs or LEPOs) that does not. In the absence of timing differences relating to cash flows associated with exercise and the dividend payment, the difference in security prices should reflect the market value of the cash dividend and imputation credits. Incorporating present value adjustments, we have the relationship between two security prices described in the paragraphs below.

Cannavan *et al.* (2004) test the accuracy of the cost-of-carry no-arbitrage pricing model in the absence of dividends. To do this, they form a sub-sample of all observations for which there is no dividend event between the trade date and the maturity of the contract. In the absence of dividends and transaction costs, we have the following relationship between the price of an ISF or LEPO on day t, with expiry on day T [$F(t,T)$], the stock price at time t [$S(t)$], the exercise price [X] and the continuously compounded risk-free rate over the period from t to T [$r_{t,T}$]. The exercise price is \$0 for ISFs and \$0.01 for LEPOs:

$$F(t,T) = S(t)e^{r^{t,T}(T-t)} - X.$$

Cannavan *et al.* (2004) then define the relative pricing error on day t [$RPE(t)$] as the difference between each side of the above equation, scaled by the stock price:

$$RPE(t) = \frac{S(t)e^{r_{t,T}(T-t)} - X - F(t,T)}{S(t)}.$$

In examining the sub-sample of stocks that did not have an ex-dividend event prior to expiry, Cannavan *et al.* (2004) were able to show that, on average, the relative pricing error is approximately zero with low dispersion. For non-dividend-paying observations, the zero mean relative pricing error suggests an absence of mispricing between stock prices and derivative prices. This provides a basis for estimating the market value of dividends based on stocks that do have an ex-dividend event prior to expiry. Our conjecture is that the relative pricing error can be explained by the market value of expected dividends and the market value of imputation credits. This is the basis for the following equation in which $r_{s,T}$ is the risk-free rate associated with the period from the ex-dividend date [s] to the expiration date [T]; $D(s)$ is a dividend with ex-dividend date $s < T$; and $IC(s)$ is the imputation credit associated with the dividend, computed as $D(s) \times \tau \div (1 - \tau) \times \%$ *Franked*. The intercept [α] represents an equilibrium transaction cost differential, which we expect to be approximately 0 given the prior evidence of a zero mean relative pricing error for non-dividend-paying stocks:

$$RPE(t) = \alpha + \delta \frac{D(s)e^{r_{s,T}(T-s)}}{S(t)} + \theta \frac{IC(s)}{S(t)}.$$

The regression version of this equation is given below. The subscript i refers to the underlying stock; the subscript j refers to the ISF or LEPO (there can be more than one derivative contract traded on the same stock at the same time with different expiration dates); and the subscript k refers to a pair of matched prices between the derivative and the underlying stock (there can be more than one pair of matched prices per day). Our objective is to explain the relative pricing error of trade k on contract j relating to the underlying stock i as a linear combination of the cash dividend and imputation credits associated with the underlying stock. Our sample includes observations in which there is either zero or one ex-dividend event prior to the expiry of the derivative:

$$RPE_{ijk}(t) = \hat{} \propto + \hat{\delta} \frac{D_i(S)e^{r_{s,T}(T-s)}}{S_i(t)} + \hat{\theta} \frac{IC_i(S)}{S_i(t)} + \epsilon_{ijk}(t).$$

The equation above is appropriate for estimating the value of imputation credits in one regime. Consistent with the analysis in Cannavan *et al.* (2004) and Beggs and Skeels (2006), we consider estimates of the value of imputation credits across multiple taxation regimes. The three tax regimes we consider are the *pre-45-day* regime, the *post-45-day/pre-rebate* regime and the *cash rebate* regime. The *pre-45-day* regime (prior to 1 July 1999) is prior to the introduction of the 45-day rule which requires investors to hold shares at risk for 45 days in order to receive the tax benefits of imputation. The *post-45-day/pre-rebate* regime (1 July 1999 to 30 June 2000) is when the 45-day rule was in effect but prior to the introduction of the cash rebate. The *cash rebate* regime (1 July 2000) onwards is when investors could receive a cash rebate for imputation credits if credits exceeded the investor's tax liability.

From the first to the second regime, we expect a decline in the value of imputation credits, and, from the second to third regime, we expect an increase in the value of imputation credits. We have no prior expectation about whether imputation credits are more or less valuable in a comparison of the first and third regimes.

Our regression model allows for variation in the estimated value of imputation credits over time and is specified below. Here, $\dot{\theta}_m$ refers to the estimated value of imputation credits in regime m for $m = 1, 2$ or 3, and $Regime_m$ takes on the value of 1 if the paired trade occurs in regime m and 0 otherwise.

$$RPE_{ijk}(t) = \hat{\propto} + \hat{\delta}\frac{D_i(s)e^{r_{s,T}(T-s)}}{S_i(t)} + \hat{\theta}_m\frac{IC_i(s)}{S_i(t)}\text{Re}gime_m + \epsilon_{ijk}$$

The structure for the regression equation in the ex-dividend dataset is the same as that for the derivatives dataset. In the regression equation below, S_{cumdiv}, S_{exdiv}, D and IC refer to cum- and ex-dividend prices, dividends and imputation credits associated with stock i and dividend j:

$$\frac{S_{cumdiv,ij} - Sexdiv, ij}{S_{cumdiv,ij}} = \hat{\alpha} + \hat{\delta}\frac{D_{ij}}{S_{sumdiv,ij}} + \hat{\theta}_m\frac{IC_{ij}}{S_{cumdiv,ij}}\text{Re}gime_m + \epsilon_{ij}.$$

In this regression specification, the estimated value of cash is held constant across the regimes. We do this as the changes to the tax laws we consider are solely concerned with imputation credits, and as such, we have reason to consider they may impact the value of credits. Further, as we have shown, random variation in ex-dividend prices (analogous to derivative prices in our dataset) leads to estimation error in values for cash and imputation credits in opposite directions. Varying both parameter estimates across regimes magnifies the impact of noise on the estimated value of credits.

In this regression specification, the estimated value of cash is held constant across the regimes. If the estimate of cash value varies across regimes, then the coefficient estimates are unduly affected. As demonstrated earlier, random variation in ex-dividend prices (analogous to futures prices in our dataset) leads to estimation error in values for cash and imputation credits in opposite directions. Varying both parameter estimates across regimes magnifies the impact of noise on the estimated value of imputation credits.

5.2. Statistical significance

Our observations are not independent. We have multiple trades on the same day relating to the same underlying stock that are priced by the same dividend expectation.

In statistical tests, the technique used to account for dependence needs to corresponds to the dependence problem in the dataset. Petersen (2009, p. 436) documented that researchers use a variety of techniques to account for dependence amongst observations and notes that 'the chosen method is often incorrect and the literature provides little guidance to researchers as to which method should be used'. Petersen's research implies that significance tests need to correctly account for the source of dependence amongst observations. In our dataset, potential dependence in error terms arises from the same ex-dividend event being associated with multiple trades and with the same firm being associated with multiple ex-dividend events.

For this reason, we construct confidence intervals using a bootstrap approach. For our two samples, we run 1,000 regressions from samples constructed by repeated sampling with replacement from our data. We report standard errors (computed as the standard deviation of coefficient estimates) and 95 percent confidence intervals from the coefficient estimates across 1,000 regressions.

We account for the dependence of observations in the compilation of data in the repeated samples. For the derivatives dataset we have 1,268 combinations of underlying stock and ex-dividend date. So, we randomly select 1,268 combinations of underlying stock and ex-dividend date, with replacement. This is equivalent to computing standard errors clustered by firm and ex-dividend event. But the advantage of the bootstrap approach is that we can demonstrate how the estimates of cash dividends and imputation credits vary with random changes in sample composition. For the ex-dividend dataset, we have 961 underlying stocks. So, each bootstrap sample involves a random selection of 961, with replacement, of all the observations for each underlying stock. This is equivalent to computing standard errors clustered by firm.

An alternative approach to using clustered standard errors is to compute averages across stocks (Armitage *et al.*, 2006). We do not take this approach because it results in a relatively small dataset for statistical tests and gives disproportionate weight to stocks that trade infrequently.[28]

6. Data

Our derivatives sample consists of 73,076 observations from the 22-year period from 16 May 1994 to 27 October 2016. We began with 75,502 observations of which 2,426 outliers were excluded.[29] Each observation comprises a match of a derivative trade and a stock trade. Table 2, Panel A, presents descriptive statistics. There are 23,293 observations with ex-dividend

[28]Armitage *et al.* (2006, table 2, p. 233) use a set of 3,803 matched trades and 73 rights issues. Each rights issue contributes an average of 52 trades. But 10 rights issues are associated with just 1 to 5 trades, for a total of 30 trades (Armitage *et al.*, 2006, pp. 242–243). This represents 0.79 percent of all trades in the sample. So applying equal weight to each rights issue means that less than 1 percent of trades are associated with 14 percent of the observations used in statistical tests.

[29]In compiling both datasets we run our regression model to identify outliers, given that a small number of influential observations can lead to spurious inferences, typically when there are large stock price changes on ex-dividend days. For each of the five regression coefficients, we removed the 0.5 percent of observations which had the largest positive or negative influence on the coefficient estimate, measured by how much the coefficient would change if the observation was removed. This resulted in the exclusion of 414 observations from the ex-dividend sample (3.1 percent) and the exclusion of 2,426 observations from the derivatives sample (3.2 percent).

Table 2
Distribution of observations across tax regimes and franking percentages

	Regime 1, pre-45-day	Regime 2, post-45-day/ pre-rebate	Regime 3, cash rebate	All
Panel A: derivatives sample				
Fully franked	1,911	263	14,735	16,909
Partially franked	50	44	3,423	3,517
Unfranked	961	197	1,709	2,867
Dividend	2,922	504	19,867	23,293
No dividend	8,101	2,171	39,511	49,783
All	11,023	2,675	59,378	73,076
Panel B: ex-dividend sample				
Fully franked	726	114	8,831	9,671
Partially franked	104	32	1,168	1,304
Unfranked	132	32	1,836	2,000
All	962	178	11,835	12,975

The table summarises the distribution of observations across tax regimes and franking credit level for two samples. The derivatives sample comprises simultaneous trades of derivatives (LEPOs and ISFs) and shares for 117 companies from 16 May 1994 to 27 October 2016. The ex-dividend sample comprises share prices on the cum- and ex-dividend dates for 961 companies from 19 January 1994 to 3 August 2021. Regime 1, the *pre-45-day* regime, is the period prior to 1 July 1999 when the 45-day rule was introduced which requires investors to hold shares at risk for 45 days in order to receive the tax benefits of imputation. Regime 2, the *post-45-day/pre-rebate* regime, is the period from 1 July 1999 to 30 June 2000, when the 45-day rule was in effect but prior to the introduction of the cash rebate. Regime 3, the *cash rebate* regime, is the period from 1 July 2000 onwards when investors could receive a cash rebate for imputation credits if credits exceeded the investor's tax liability. For the derivatives sample, 'no dividend' means that there was no ex-dividend event between the trade date and the expiration of the derivative contract.

dates prior to the expiration of the derivative (32 percent of the sample). Within this sub-sample, 73 percent of observations are associated with fully franked dividends, 15 percent of observations are associated with partially franked dividends and 12 percent of observations are associated with unfranked dividends. The derivatives dataset comprises 117 unique stocks (Table 3, Panel A) with the top 20 stocks contributing 84 percent of observations. The derivatives dataset was obtained from SIRCA.

The dividend drop-off sample comprises 12,975 observations from 19 January 1994 to 3 August 2021 (Table 2, Panel B). We began with 13,913 observations of which 414 outliers were excluded and 524 observations were excluded because they had extreme high or low dividend yields (262 dividend yields > 10 percent and 262 dividend yields < 0.3822 percent). The ex-dividend dataset comprises 961 unique stocks (Table 3, Panel B), with the top 20 stocks contributing 8 percent of observations. The ex-dividend dataset was obtained from Refinitiv.

Table 3
Distribution of observations by stock and tax regime

	Regime 1, pre-45-day	Regime 2, post-45-day/ pre-rebate	Regime 3, cash rebate	All
Panel A: derivatives sample				
BHP	5,332	825	7,683	13,840
National Australia Bank	1,257	377	4,940	6,574
Commonwealth Bank	30	46	5,618	5,694
Rio Tinto	11	53	5,524	5,588
News Corporation	1,429	354	2,021	3,804
ANZ	235	161	3,375	3,771
Westpac	308	130	2,966	3,404
Newcrest	0	0	2,272	2,272
Western Mining	1,392	274	421	2,087
Woodside	20	15	1,985	2,020
Babcock & Brown	0	0	1,946	1,946
Telstra	0	70	1,584	1,654
AMP	0	39	1,488	1,527
Woolworths	1	16	1,500	1,517
Macquarie	0	0	1,451	1,451
Wesfarmers	0	0	1,191	1,191
QBE	0	0	802	802
St George Bank	0	0	731	731
Qantas	7	17	698	722
MIM	515	66	107	688
Other	486	232	11,075	11,793
All	11,023	2,675	59,378	73,076
Panel B: ex-dividend sample				
CSR	11	2	42	55
Perpetual	8	3	44	55
Bendigo & Adelaide Bank	10	2	42	54
Lendlease	12	1	41	54
Orica	10	2	42	54
Woolworths	10	2	42	54
Brambles	10	2	41	53
Suncorp	10	0	43	53
Westpac	10	2	41	53
ANZ	10	2	40	52
BHP	10	2	40	52
Commonwealth Bank	10	2	40	52
Wesfarmers	10	0	42	52
ALS	9	1	41	51
Coca-Cola Amatil	7	2	42	51
National Australia Bank	11	1	39	51
Woodside	7	2	42	51
Bank of Queensland	11	0	39	50
CSL	9	2	39	50

(continued)

Table 3 (continued)

	Regime 1, pre-45-day	Regime 2, post-45-day/ pre-rebate	Regime 3, cash rebate	All
Cimic	11	1	38	50
Other	766	147	11,015	11,928
All	962	178	11,835	12,975

The table summarises the distribution of observations across tax regimes and firms for two samples. The derivatives sample comprises simultaneous trades of derivatives (LEPOs and ISFs) and shares for 117 companies from 16 May 1994 to 27 October 2016. The ex-dividend sample comprises share prices on the cum- and ex-dividend dates for 961 companies from 19 January 1994 to 3 August 2021. Regime 1, the *pre-45-day* regime, is the period prior to 1 July 1999 when the 45-day rule was introduced which requires investors to hold shares at risk for 45 days in order to receive the tax benefits of imputation. Regime 2, the *post-45-day/pre-rebate* regime, is the period from 1 July 1999 to 30 June 2000, when the 45-day rule was in effect but prior to the introduction of the cash rebate. Regime 3, the *cash rebate* regime, is the period from 1 July 2000 onwards when investors could receive a cash rebate for imputation credits if credits exceeded the investor's tax liability.

In Table 4, we present descriptive statistics for the regression variables. With respect to the derivatives sample, for observations without an ex-dividend event prior to the expiration date for the derivative, the average relative pricing error is 0.04 percent and remains close to zero across all three tax regimes. For observations with an ex-dividend event prior to the expiration date for the derivative, the average relative pricing error is 1.72 percent, the average dividend yield is 1.76 percent and the average imputation credit yield is 0.67 percent. The averages provide prima facie evidence that a fully franked dividend package is not fully valued by the market. If the market placed full value on a fully franked dividend package, the average relative pricing error would 2.44 percent. Although the average relative pricing error is close to zero for observations without an associated dividend, the relative pricing error varies across the sample. Across all observations without an associated dividend, the standard deviation of the relative pricing error is 0.39 percent, and the standard deviation of the relative pricing error is highest in the *post-45-day/pre-rebate* regime at 0.62 percent.

With respect to the ex-dividend sample, the average dividend yield is 2.40 percent, the average imputation credit yield is 0.85 percent and the average change in price on the ex-dividend date is 2.05 percent. Again, there is prima facie evidence that the package of a fully franked dividend is not fully valued. If it was, the average ex-dividend price change would be 3.24 percent.

There is also prima facie evidence from both samples that the share market places at least some positive value on imputation credits. Compare the average relative pricing error to the dividend yield for stocks paying unfranked dividends, partially franked dividends and fully franked dividends. On average,

Table 4
Relative pricing error, dividend yield and imputation credit yield

	Regime 1, pre-45-day	Regime 2, post-45-day/pre-rebate	Regime 3, cash rebate	Un-franked	Partial	Franked	All
Panel A: Derivatives sample							
Mean							
No dividend prior to expiry							
Relative pricing error (%)	−0.02	−0.01	0.06	0.02	0.07	0.04	0.04
Dividend prior to expiry							
Relative pricing error (%)	1.48	1.09	1.78	1.03	1.38	1.91	1.72
Dividend yield (%)	1.49	1.25	1.82	1.10	1.42	1.95	1.76
Imputation credit yield (%)	0.60	0.49	0.69	0.00	0.33	0.86	0.67
Standard deviation							
No dividend prior to expiry							
Relative pricing error (%)	0.44	0.60	0.37	0.49	0.48	0.35	0.39
Dividend prior to expiry							
Relative pricing error (%)	0.96	0.79	1.05	0.91	0.87	1.02	1.04
Dividend yield (%)	0.87	0.75	0.92	0.91	0.82	0.87	0.92
Imputation credit yield (%)	0.52	0.45	0.45	0.00	0.28	0.38	0.46
Panel B: Ex-dividend sample							

(continued)

Table 4 (continued)

	Regime 1, pre-45-day	Regime 2, post-45-day/pre-rebate	Regime 3, cash rebate	Un-franked	Partial	Franked	All
Mean							
Change in price (%)	1.93	1.62	2.07	1.70	1.91	2.14	2.05
Dividend yield (%)	2.46	2.26	2.39	2.26	2.36	2.43	2.40
Imputation credit yield (%)	1.07	0.81	0.83	0.00	0.48	1.07	0.85
Standard deviation							
Change in price (%)	2.01	1.59	2.75	2.32	2.41	2.78	2.69
Dividend yield (%)	1.12	1.06	1.30	1.29	1.18	1.30	1.29
Imputation credit yield (%)	0.70	0.60	0.64	0.00	0.35	0.58	0.65

The table presents descriptive statistics for two samples. The derivatives sample comprises simultaneous trades of derivatives (LEPOs and ISFs) and shares for 117 companies from 16 May 1994 to 27 October 2016. Relative pricing error is the percentage difference in the derivative price and the share price. Dividend yield is the dividend relative to share price for the next ex-dividend event, provided it occurs prior to the expiration date for the derivative. Imputation credit yield = dividend yield × franking percentage × corporate tax rate ÷ (1 – corporate tax rate). The ex-dividend sample comprises share prices on the cum- and ex-dividend dates for 961 companies from 19 January 1994 to 3 August 2021. Percentage change in price is the cum-dividend price minus the ex-dividend price, scaled by the cum-dividend price. Dividend yield is the cash dividend scaled by the cum-dividend price. Imputation credit yield = dividend yield × franking percentage × corporate tax rate ÷ (1 – corporate tax rate). Regime 1, the *pre-45-day* regime, is the period prior to 1 July 1999 when the 45-day rule was introduced which requires investors to hold shares at risk for 45 days in order to receive the tax benefits of imputation. Regime 2, the *post-45-day/pre-rebate* regime, is the period from 1 July 1999 to 30 June 2000, when the 45-day rule was in effect but prior to the introduction of the cash rebate. Regime 3, the *cash rebate* regime, is the period from 1 July 2000 onwards when investors could receive a cash rebate for imputation credits if credits exceeded the investor's tax liability.

for stocks paying unfranked dividends, the average RPE is 94 percent of the dividend yield (1.03 percent relative to 1.10 percent). This ratio increases to 97 percent for stocks paying partially franked dividends and to 98 percent for stocks paying fully franked dividends. With respect to the ex-dividend sample, the corresponding ratios are 0.76, 0.81 and 0.88.

To make this inference more robust we ran a simple regression of RPE or ex-dividend price changes on dividend yield interacted with dummy variables for each of the three tax regimes. We ran the regression separately for observations in which the dividends were unfranked, partially franked or fully franked. Coefficient estimates and standard errors are presented in Table 5. For the derivatives sample, standard errors are clustered by firm and ex-dividend date. For the ex-dividend sample, standard errors are clustered by firm.

The regression shows that, for both samples, the coefficient on dividend yield is higher for fully franked dividends compared to unfranked dividends, with this result being consistent across tax regimes. The regression also shows that, for observations with unfranked dividends and fully franked dividends,

Table 5
Preliminary comparison

	Coefficient			Standard error		
Parameter	None	Partial	Full	None	Partial	Full
Panel A: Derivatives sample						
Intercept (%)	0.024	0.074	0.046	0.013	0.035	0.007
Pre-45 day regime	0.928	0.940	0.992	0.039	0.022	0.018
Post-45 day/pre-rebate regime	0.836	0.810	0.865	0.031	0.027	0.011
C*ash rebate* regime	0.895	0.918	0.951	0.023	0.036	0.012
Observations	11,442	8,358	53,276			
R^2 (%)	61.24	74.97	81.90			
Panel B: Ex-dividend sample						
Intercept (%)	−0.018	0.179	−0.196	0.092	0.135	0.071
Pre-45 day regime	0.750	0.437	0.908	0.057	0.099	0.045
Post-45 day/pre-rebate regime	0.564	0.691	0.837	0.096	0.102	0.049
C*ash rebate* regime	0.769	0.763	0.967	0.038	0.058	0.034
Observations	2,000	1,304	9,671			
R^2 (%)	17.91	13.89	20.32			

The table presents the results of a regression of relative pricing error (for the derivatives sample) on the percentage change in price (for the ex-dividend sample) on dividend yield interacted with dummy variables corresponding to three tax regimes (the *pre-45-day regim*e is prior to 1 July 1999, the *post-45-day/pre-rebate* regime is from 1 July 1999 to 30 June 2000, and the *cash rebate* regime is from 1 July 2000 onwards). The regression was run separately for stocks with unfranked dividends, partially franked dividends and fully franked dividends. For the derivatives sample, standard errors are clustered by firm and ex-dividend event. For the ex-dividend sample, standard errors are clustered by firm.

coefficients decrease from the *pre-rebate* regime to the *post-45-day/pre-rebate* and then increase again as we progress to the *cash rebate* regime.

These simple regressions could be used to infer the value of imputation credits. For example, in the *cash rebate* regime, the coefficient on dividend yield for the unfranked dividend is 0.90 compared to 0.95 for a fully franked dividend. The difference in coefficient estimates of 0.05 implies that an imputation credit is worth 13 cents in the dollar (0.05 ÷ 0.3 / (1 – 0.30) = 0.13). For the ex-dividend sample the implied value of a credit in the cash rebate regime is 0.46 (from a difference in coefficient estimates of 0.20). But despite there being no correlated variables we still have a joint estimation issue. Any noise in the data that leads to an increase (or decrease) in the estimated value of cash necessarily leads to a decrease (or increase) in the estimated value of credits. It is also challenging to make an inference about the impact of the cash rebate tax law change from the preliminary regressions. The coefficient on dividend yield for franked dividends increased (0.87 to 0.97 in the derivatives sample and 0.84 to 0.97 in the ex-dividend sample), but the coefficient on dividend yield for unfranked dividends also increased (from 0.84 to 0.90 in the derivatives sample and 0.56 to 0.77 in the ex-dividend sample).

In short, we have preliminary evidence that dividends with imputation credits attached are more valuable than dividends without imputation credits attached. To estimate the value of credits and confidence intervals across tax regimes we turn to the multivariate analysis.

7. Results

7.1. Derivatives sample results

We begin with point estimates for the derivatives sample (Table 6, Panel A). The estimated value of cash dividends is 0.91 of face value. The estimated value for imputation credits (as a proportion of face value) is 0.16 in the *pre-45-day* regime, −0.09 in the *post-45-day/pre-rebate* regime and 0.11 in the *cash rebate* regime. The directional change in the estimated value of imputation credits is consistent with changes in the tax law. Credits decrease in value with the introduction of the 45-day rule and increase in value when the cash rebate is introduced. We also present estimates of the value of a fully franked dividend: 0.97 in the *pre-45-day* regime, 0.87 in the *post-45-day/pre-rebate* regime and 0.95 in the *cash rebate* regime.

Recall that we compile 1,000 randomly-generated samples of 1,268 firm/ex-dividend combinations by re-sampling with replacement. The 3,000 points shown in Figure 5, Panel A represent the estimates of cash value and imputation credit value across the three tax regimes. This illustrates the impact that random variation across samples has on *joint* parameter estimates: Samples with low estimated values for cash had high estimated values for

Table 6
Results

Parameter	Coefficient	SE	Conf interval
Panel A: Derivatives sample			
Intercept (%)	0.045	0.007	0.03 to 0.06
Cash	0.906	0.017	0.87 to 0.94
Credit *pre-45 day*	0.161	0.048	0.06 to 0.25
Credit *post-45 day/pre-rebate*	−0.090	0.039	−0.18 to −0.02
Credit in *cash rebate* regime	0.106	0.048	0.01 to 0.20
Fully franked div *pre-45 day*	0.975	0.016	0.94 to 1.00
Fully franked div *post-45 day/pre-rebate*	0.867	0.010	0.84 to 0.88
Fully franked div in *cash rebate* regime	0.951	0.012	0.93 to 0.97
Observations	73,076		
R^2 (%)	79.77		
Panel B: Ex-dividend sample			
Intercept (%)	−0.132	0.056	−0.24 to −0.03
Cash	0.797	0.025	0.75 to 0.85
Credit *pre-45 day*	0.117	0.066	−0.01 to 0.25
Credit *post-45 day/pre-rebate*	0.042	0.080	−0.12 to 0.20
Credit in *cash rebate* regime	0.344	0.059	0.23 to 0.46
Fully franked div *pre-45 day*	0.848	0.033	0.79 to 0.92
Fully franked div *post-45 day/pre-rebate*	0.815	0.037	0.75 to 0.89
Fully franked div in *cash rebate* regime	0.945	0.029	0.89 to 1.00
Observations	12,975		
R^2 (%)	19.68		

The table presents results of a regression of relative pricing error (for the derivatives sample) or percentage price change (for the ex-dividend sample) on cash dividend yield and imputation credit yield interacted with dummy variables corresponding to three tax regimes (the *pre-45-day regime* is prior to 1 July 1999, the *post-45-day/pre-rebate* regime is from 1 July 1999 to 30 June 2000, and the *cash rebate* regime is from 1 July 2000 onwards). The standard error and confidence intervals are computed from a bootstrap analysis based upon 1,000 samples drawn from our data. For each derivatives sample we randomly select, with replacement, 1,268 firm/ex-dividend event pairs from the full suite of 1,268 firm/ex-dividend event combinations in our dataset of 73,076 observations. For the ex-dividend sample we randomly select, with replacement, 961 firms from the full suite of 961 firms in our dataset of 12,975 ex-dividend events. The standard errors are the standard deviations of coefficient estimates across 1,000 regressions, and the confidence intervals are the middle 95 percent of coefficient estimates. The estimates labelled fully franked dividend are for the package of a dollar of cash dividend with full imputation, relative to the face value of cash (that is, a one dollar fully franked dividend has an estimated value of $0.951 in the *cash rebate* regime from the derivatives sample, and an estimated value of $0.945 in the *cash rebate* regime from the ex-dividend sample).

imputation credits. It should also be noted that the regression had a condition index of 3.4 and a variance inflation factor of 2.5, which prior research considers indicative of acceptable levels of collinearity between variables.

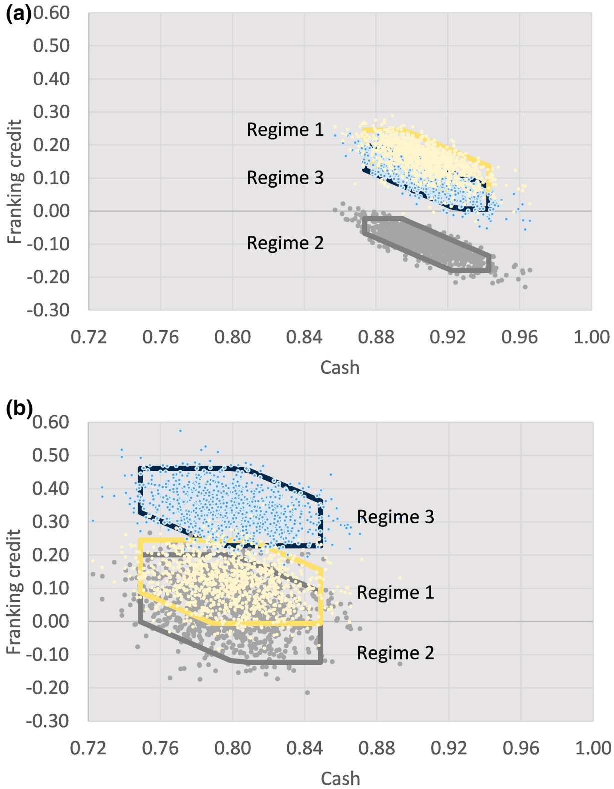

Figure 5 Estimates of the value of cash dividends and imputation credits across tax regimes.The figure presents results of a regression of relative pricing error (for the derivatives sample) or percentage price change (for the ex-dividend sample) on cash dividend yield and imputation credit yield interacted with dummy variables corresponding to three tax regimes (the *pre-45-day regim*e is prior to 1 July 1999, the *post-45-day/pre-rebate* regime is from 1 July 1999 to 30 June 2000, and the *cash rebate* regime is from 1 July 2000 onwards). Each datapoint represents the combination of estimated cash value and estimated credit value by regime across 1,000 simulated samples. For each derivatives sample we randomly select, with replacement, 1,268 firm/ex-dividend event pairs from the full suite of 1,268 firm/ex-dividend event combinations in our dataset of 73,076 observations. For the ex-dividend sample we randomly select, with replacement, 961 firms from the full suite of 961 firms in our dataset of 12,975 ex-dividend events.

The standard errors shown in Table 6 are the standard deviations of each parameter estimate; and the 95 percent confidence intervals represent the middle 950 parameter estimates for each coefficient. We verified that the standard errors reported in Table 6 are the same as generated by an assumption that standard errors are clustered by firm/ex-dividend event. In the Appendix (Table A1) we present results from a bootstrap analysis in which we randomly select individual observations with replacement. The results from the independence assumption are the same as generated by a typical OLS regression with an assumption that observations are independent. We report the results in Appendix Table A1 to demonstrate that standard errors are likely to be understated, and therefore statistical significance overstated, if an independence assumption is made when it is not valid.

For the derivatives sample, the 95 percent confidence intervals for the value of imputation credits are 0.06 to 0.25 in the *pre-45-day* regime, −0.18 to −0.02 in the *post-45-day/pre-rebate* regime and 0.01 to 0.20 in the *cash rebate* regime. Table 6 also shows standard errors and confidence intervals for a fully franked dividend. The table shows that the package value of a fully franked dividend can be estimated with more precision than the individual components of cash value and imputation credit value (the standard errors are 25 percent to 35 percent of the standard errors associated with imputation credits). A fully franked dividend package has an estimated value of 0.94 to 1.00 of the cash dividend face value in the *pre-45-day* regime, 0.84 to 0.88 in the *post-45-day/pre-rebate* regime and 0.93 to 0.97 in the *cash rebate* regime.

This narrower range for the value of a fully franked dividend package constrains the implied value for imputation credits. For example, in the *cash rebate* regime, while the value of imputation credits could be as high as 0.20, and cash value could be as high as 0.94, the evidence is inconsistent with credits being worth 0.20 *and* cash being worth 0.94. Under these two assumptions the value of a fully franked dividend package would be 1.03 of the cash dividend face value,[30] which is above the 95 percent confidence interval of 0.93 to 0.97 already determined. By the same analogy the data is inconsistent with imputation credits being worth 0.01 *and* cash being worth 0.87. These joint estimates of the value of credits and cash would imply a fully franked dividend package is worth 0.88,[31] which lies below the established lower bound of the confidence interval for a fully franked dividend.

To interpret the value of imputation credits and cash jointly, we compile the suite of parameter estimates that are consistent with the confidence intervals for fully franked dividends in each tax regime, and which also lie within the confidence intervals for imputation credit value and cash value (Figure 5, solid lines). The numbers at the bottom of the chart in Figure 5, Panel A, provide more detail for specific assumptions related to the value of cash dividends. The blue section labelled 'Regime 3' in Figure 5 refers to the cash rebate regime and has the following implications;

- At the lower bound estimate for the value of cash (0.87) the estimated value for imputation credits is 0.13 to 0.20.

[30] $0.943 + 0.197 \times 0.30 \div (1 - 0.30) = 0.943 + 0.084 = 1.027$.

[31] $0.874 + 0.006 \times 0.30 \div (1 - 0.30) = 0.874 + 0.003 = 0.876$.

The lower bound (0.13) is constrained by the lower bound of the confidence interval for the value of a fully franked dividend (0.93), as 0.87 + 0.13 × 0.30 ÷ (1 – 0.30) = 0.87 + 0.05 = 0.93.
The upper bound (0.20) is constrained by the upper bound of the confidence interval for the value of an imputation credit (0.20).

- At the coefficient estimate for the value of cash (0.91) the estimated value for imputation credits is 0.05 to 0.16.
  The lower bound (0.05) is constrained by the lower bound of the confidence interval for a fully franked dividend (0.93), as 0.91 + 0.05 × 0.30 ÷ (1 – 0.30) = 0.91 + 0.02 = 0.93.
  The upper bound (0.16) is constrained by the upper bound of the confidence interval for a fully franked dividend (0.97), as 0.91 + 0.16 × 0.30 ÷ (1 – 0.30) = 0.91 + 0.07 = 0.97.
- At the upper bound estimate for the value of cash (0.94) the estimated value for imputation credits is 0.01 to 0.07.
  The lower bound (0.01) is constrained by the lower bound of the confidence interval for an imputation credit (0.01).
  The upper bound (0.07) is constrained by the upper bound for the value of a fully franked dividend (0.97), as 0.94 + 0.07 × 0.30 ÷ (1 – 0.30) = 0.94 + 0.03 = 0.97.

Figure 5 shows a wider range of plausible values for imputation credits in the *pre-45-day* regime, and in the *post-45-day/pre-rebate* regime. This can be attributed to the smaller sample sizes in these regimes. The full range of imputation credit values in the *pre-45-day* regime is −0.04 to 0.30, and the full range of imputation credit values in the *post-45-day/pre-rebate* regime is −0.28 to 0.06. Again, these ranges cannot be used independently of an estimated value for cash dividends. Assuming cash is worth 88 cents in the dollar, imputation credit value was 0.11 to 0.30 in the *pre-45-day* regime, which decreases to −0.14 to 0.06 in the *post-45-day/pre-rebate* regime. Assuming cash is worth 98 cents in the dollar, imputation credit value was −0.04 to 0.16 in the *pre-45-day* regime, which decreases to −0.28 to −0.08 in the *post-45-day/pre-rebate* regime.

Comparing results across tax regimes, it is likely that changes in the tax law positively affected the value of imputation credits. A fully franked dividend had an estimated value of 0.94 to 1.00 in the *pre-45-day* regime, which decreased to 0.84 to 0.88 in the *post-45-day/pre-rebate* regime and which increased again to 0.93 to 0.97 in the *cash rebate* regime. Of particular interest is the value of credits in the *cash rebate* regime, which take on a value of 0.01 to 0.20. But importantly, the conclusion that credits are worth 20 cents in the dollar can only be reached if we also conclude that cash is worth no more than 89 cents in the dollar (consistent with the upper bound package value of 0.97); and the conclusion that credits are worth 1 cent in the dollar can only be reached if we conclude that cash is worth at least 93 cents in the dollar (consistent with the lower bound package value of 0.93).

7.2. Ex-dividend sample results

For the ex-dividend sample, the coefficient estimate for cash value is 0.80, and the coefficient estimates for credit value are 0.12 for in the *pre-45-day* regime, 0.04 in the *post-45-day/pre-rebate* regime and 0.34 in the *cash rebate* regime (Table 6, Panel B). The estimated value of a fully franked dividend package (expressed as a proportion of the cash dividend face value) is 0.85 in the *pre-45-day* regime, 0.82 in the *post-45-day/pre-rebate* regime and 0.94 in the *cash rebate* regime. As with the derivatives sample, credit value decreases with the introduction of the 45-day rule and increases with the introduction of the cash rebate.

Our bootstrap analysis of ex-dividend day price changes is formed by randomly selecting from 961 firms with replacement to create 1,000 randomly-generated samples. Observations of ex-dividend day price changes are not independent because firms have persistent characteristics like liquidity, investor base, index membership and analyst coverage. Ninety five percent of samples have observations within the range of 12,185 to 13,817. The scatter plots shown in Panel B of Figure 5 have more dispersion than those from the derivatives sample. This is due to greater dispersion in the underlying data (for example, the standard deviation of relative pricing error for dividend-paying stocks in the derivatives sample is 1.04 percent compared to the standard deviation of ex-dividend price changes of 2.69 percent); and because there are fewer observations in the ex-dividend sample versus the derivatives sample (12,975 versus 73,076). As with the derivatives sample, there is an inverse relationship between the estimated values for cash and the estimated values for credits. The regression generated a condition index of 6.3 and a variance inflation factor of 2.3. The standard errors shown in Table 6, Panel B, computed as the standard deviations of coefficient estimates across samples, are equivalent to standard errors clustered by firm.

For the ex-dividend sample, the 95 percent confidence intervals for the value of imputation credits are −0.01 to 0.25 in the *pre-45-day* regime, −0.12 to 0.20 in the *post-45-day/pre-rebate* regime and 0.23 to 0.46 in the *cash rebate* regime. A fully franked dividend package has an estimated value of 0.79 to 0.92 of the face value of the cash dividend in the *pre-45-day* regime, 0.75 to 0.89 in the *post-45-day/pre-rebate* regime and 0.89 to 1.00 in the *cash rebate* regime.

Based upon the estimates reported at the bottom of the chart in Figure 5 we can make inferences about the value of imputation credits under alternative estimates for the value of cash. With respect to the *cash rebate* regime we have the following estimates:

- At the lower bound estimate for the value of cash (0.75) the estimated value for imputation credits is 0.33 to 0.46.
  The lower bound (0.33) is constrained by the lower bound of the confidence interval for the value of a fully franked dividend (0.89), as $0.75 + 0.13 \times 0.30 \div (1 - 0.30) = 0.75 + 0.14 = 0.89$.

The upper bound (0.46) is constrained by the upper bound of the confidence interval for the value of an imputation credit (0.46).

- At the coefficient estimate for the value of cash (0.80) the estimated value for imputation credits is 0.23 to 0.46.
  The lower bound (0.23) is constrained by the lower bound of the confidence interval for a fully franked dividend (0.89), as $0.80 + 0.23 \times 0.30 \div (1 - 0.30) = 0.80 + 0.10 = 0.89$.
  The upper bound (0.46) is constrained by the upper bound of the confidence interval for a fully franked dividend (1.00), as $0.80 + 0.46 \times 0.30 \div (1 - 0.30) = 0.80 + 0.20 = 1.00$.
- At the upper bound estimate for the value of cash (0.85) the estimated value for imputation credits is 0.23 to 0.36.
  The lower bound (0.23) is constrained by the lower bound of the confidence interval for an imputation credit (0.23).
  The upper bound (0.36) is constrained by the upper bound for the value of a fully franked dividend, as $0.85 + 0.36 \times 0.30 \div (1 - 0.30) = 0.85 + 0.16 = 1.00$.

There are not enough observations to make inferences about the imposition of the 45-day trading rule on the value of credits (the scatter plots for regions 1 and 2 overlap). But there is persuasive evidence that the introduction of the cash rebate led to an increase in the value of imputation credits, consistent with the results from the derivatives sample. The confidence intervals for the value of credits (0.23 to 0.46) and the value of a fully franked dividend (0.89 to 1.00) are above the corresponding confidence intervals in the earlier regimes.

According to the dividend drop-off analysis, in the *cash rebate* regime, credits could be worth as much as 46 cents in the dollar (but only if a dollar of cash is assumed to be worth no more than 0.81, given the upper bound of the confidence interval for a fully franked dividend package); and credits could be worth as little as 23 cents in the dollar (but only if a dollar of cash is assumed to be worth at least 0.79, given the lower bound of the confidence interval for the value of a fully franked dividend package).

8. Conclusion

The estimation of the market value of dividend imputation tax credits is of central importance to valuation in markets with imputation tax systems. Estimation of the value of imputation credits is complicated by the need to simultaneously estimate the value of the cash dividend to which the credits are attached. Having shown how the joint estimation and joint interpretation of both estimates is critical for correct inference, we provide an empirical analysis that combines, for the first time in the literature, the use of both matched derivatives-shares trades and dividend drop-off analysis within one comprehensive empirical investigation.

Using more than 73,000 derivative prices, and 12,000 ex-dividend day prices, we present the suite of combinations of credit value and cash value under three different tax regimes (Figure 5). In the current tax regime, under which investors can receive a cash rebate for imputation credits:

- In the derivatives sample, the estimated market value of credits lies within the range of 0.01 to 0.20. A dollar of cash is estimated to be valued by the market at between 87 cents and 94 cents. At the lower end of cash value (0.87), credits are worth 0.13 to 0.20 of face value, and, at the higher end of cash value (0.94), credits are worth 0.01 to 0.07 of cash value. A fully franked dividend package is valued by the market within the range of 0.93 to 0.97 of cash dividend face value.
- In the ex-dividend sample, the estimated market value of credits lies within the range of 0.23 to 0.46 of face value (higher than implied by the derivatives sample) and cash is valued by the market at 0.75 to 0.85 of face value (lower than implied by the derivatives sample). At the lower end of cash value (0.75), credits are worth 0.33 to 0.46, and, at the higher end of cash value (0.85), credits are worth 0.23 to 0.36. The estimated value of a fully franked dividend package is 0.89 to 1.00 of cash dividend face value, which spans the confidence interval based upon the derivatives sample.

There are two findings that are consistent with both samples. First, the introduction of the cash rebate increased the value of imputation credits. Second, a fully franked one dollar dividend is valued in the market at a little under a dollar.

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Appendix

Table A1
Results if observations are assumed to be independent

Parameter	Coefficient	SE	Conf interval
Panel A: Derivative prices			
Intercept (%)	0.045	0.002	0.04 to 0.05
Cash	0.906	0.004	0.90 to 0.91
Credit *pre-45 day*	0.161	0.011	0.14 to 0.18
Credit *post-45 day/pre-rebate*	−0.090	0.014	−0.12 to −0.06
Credit in *cash rebate* regime	0.106	0.011	0.08 to 0.13
Fully franked div *pre-45 day*	0.975	0.003	0.97 to 0.98
Fully franked div *post-45 day/pre-rebate*	0.867	0.005	0.86 to 0.88
Fully franked div in *cash rebate* regime	0.951	0.003	0.95 to 0.96
Observations	73,076		
R^2 (%)	79.77		
Panel B: Dividend drop-off			
Intercept (%)	−0.132	0.043	−0.22 to −0.05
Cash	0.797	0.021	0.76 to 0.84
Credit *pre-45 day*	0.117	0.049	0.02 to 0.21
Credit *post-45 day/pre-rebate*	0.042	0.078	−0.12 to 0.19
Credit in *cash rebate* regime	0.344	0.046	0.25 to 0.43
Fully franked div *pre-45 day*	0.848	0.022	0.80 to 0.89
Fully franked div *post-45 day/pre-rebate*	0.815	0.035	0.74 to 0.88
Fully franked div in *cash rebate* regime	0.945	0.019	0.90 to 0.98
Observations	12,975		
R^2 (%)	19.68		

The table presents results of a regression of relative pricing error (for the derivatives sample) or percentage price change (for the ex-dividend sample) on cash dividend yield and imputation credit yield interacted with dummy variables corresponding to three tax regimes (the *pre-45-day regim*e is prior to 1 July 1999, the *post-45-day/pre-rebate* regime is from 1 July 1999 to 30 June 2000, and the *cash rebate* regime is from 1 July 2000 onwards). The standard error and confidence intervals are computed from a bootstrap analysis based upon 1,000 samples drawn from our data. For each derivatives sample we randomly select, with replacement, 73,076 observations from our full dataset of 73,076 observations. For the ex-dividend sample we randomly select, with replacement, 12,975 observations from our full dataset of 12,975 ex-dividend events. The standard errors are the standard deviations of coefficient estimates across 1,000 regressions, and the confidence intervals are the middle 95 percent of coefficient estimates. The estimates labelled fully franked dividend are for the package of a dollar of cash dividend with full imputation, relative to the face value of cash (that is, a one dollar fully franked dividend has an estimated value of $0.951 in the *cash rebate* regime from the derivatives sample, and an estimated value of $0.945 in the *cash rebate* regime from the ex-dividend sample).