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Investigation of the costly-arbitrage model of price formation around the ex-dividend day in Norway ☆

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ABSTRACT

We estimate the costly-arbitrage model of Boyd and Jagannathan [Boyd, John, and Jagannathan, Ravi, 1994, Ex-Dividend Price Behavior of Common Stocks, Review of Financial Studies 7, 711–741.] using Norwegian stock market data. Taxable distributions take place at two separate dates, one that entails the distribution of an imputation-tax credit and another the distribution of the cash dividend. We find that the costly-arbitrage model is consistent with observed stock returns around the ex-dividend day, but the model cannot explain the return patterns around the distribution of the tax credit. We conclude that uncertainty about the cash flows prevents arbitrage.

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1. Introduction

An extensive empirical literature documents abnormal stock returns over the ex-dividend day. Researchers focus on four explanatory variables. Elton and Gruber (1970) emphasize the asymmetric taxation of dividends and capital gains. They suggest that abnormal before-tax returns compensate the marginal investor for higher personal tax on dividends. This view is challenged by Kalay (1982) who focuses on the role of costly arbitrage. He suggests that tax-neutral arbitrageurs eliminate profit opportunities and argues that abnormal stock returns reflect the transaction costs of arbitrage. Heath and Jarrow (1988), in turn, argue that

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arbitrageurs are risk averse and cannot take unlimited long or short positions. They suggest, instead, that abnormal stock returns constitute a premium for excess risk taking. Lastly, Bali and Hite (1998) and Frank and Jagannathan (1998) propose microstructure-based arguments, which provide an alternative to tax-based explanations.

In this paper, we re-examine some of these issues using data from Norway. The Norwegian stock market is interesting because yearly taxable distributions take place at two separate dates. The first date is the distribution of an imputation-tax credit that shields shareholders from capital gains tax on undistributed corporate profits. The second date is the payment of the cash dividend. We estimate the costly-arbitrage model of Boyd and Jagannathan (1994) and find that the price formation around the two dates is remarkably different despite the fact that the same group of arbitrageurs can trade around both distributions. The structural estimation is consistent with the costly-arbitrage model of price formation around the ex-dividend day, but we reject the model for the tax credit.

We argue that uncertainty about the cash flows is critical. While the cash dividend is known to all traders at the time of the distribution, the imputation-tax credit is uncertain. The tax credit comes in the form of a basis step-up that reduces capital gains tax liability. The arbitrageur must estimate the amount of the basis step-up, and therefore faces the risk of overestimating the step-up amount and overpaying for it. This risk is diversifiable and can be avoided by purchasing a portfolio of stocks that carry tax credits, but the low liquidity of most Norwegian stocks makes diversification costly. Uncertainty about the cash flows implies that the tax arbitrage position may require equity financing. If equity is scarce, a large position in a portfolio of stocks that carry tax credits may prevent the arbitrageur from taking on more profitable trades later in the year.

We also consider the role of legal risk. The Norwegian tax authorities reserve the right to nullify transactions which serve no other purposes than to avoid taxes. The arbitrageur must take into consideration the risk that the avoided taxes must be paid along with fines and loss of reputation capital. In the middle of the sample period, the Norwegian tax authorities audited the leading banks and brokerage houses for excessive dividend capture. Before the tax audit, we find that foreign shareholders on average sell 0.55% of the outstanding shares to domestic banks and corporations prior to the ex-dividend day and then re-establish their position afterwards. After the audit, tax-related trading volume is negligible. However, the costly-arbitrage model is consistent with the observed return patterns around the ex-dividend day both before and after the audit, so we conclude that legal risk does not matter for price formation.

The outcome of tax arbitrage matters to security-issuing firms. The results of the structural estimation suggest that the imputation-tax credit is not fully capitalized, which implies that firms do not capture the full benefit of the tax credit granted by the government when they issue securities. Arbitrage also concerns tax authorities who are responsible for tax collection and tax code design. The market response to the tax audit suggests that legal risk influences the volume of tax arbitrage and therefore tax revenue. Finally, arbitrage affects investors who take the other side of the trade. Our estimation results suggest that investors capture the rents from trading the cash dividend, while investors and arbitrageurs split the rents from trading the tax credit.

Section 2 explains the relevant tax rules, Section 3 derives the hypotheses, and Section 4 reports the empirical results. We conclude the paper in Section 5 with a survey of the international evidence. The return patterns around the distribution of the dividend and the tax credit in Norway are general across several studies.

2. Tax environment

This section explains the taxation of dividends and capital gains in Norway from 1992 to 2006. The taxation of dividends is simple. Domestic shareholders earn tax-free dividends, while dividends paid to foreign shareholders are subject to a withholding tax. The withholding tax rate is 15% for OECD countries and 25% for most other countries.[1] The first objective of our paper is to investigate how the tax asymmetry between domestic and foreign shareholders influences return and volume patterns around the ex-dividend day.

The taxation of capital gains is more complicated. Individuals and businesses are taxed at the 28% rate on realized capital gains. The tax rate is proportional and does not depend on the time that elapses between the purchase and the sale of the shares. Tax-exempt organizations and foreign shareholders do not pay capital gains tax in Norway. While these tax rules are simple, the calculation of the capital gain is complicated. Norway has an imputation-tax system, where the tax authorities first collect corporate tax from the firm and then give the corporate tax back to shareholders in the form of a tax credit. The purpose of the tax credit is to neutralize the effects of double taxation. In most countries with imputation-tax systems, the refund of corporate tax is partial. Shareholders are given a tax credit for corporate tax on dividends, while retained earnings that generate taxable capital gains for shareholders are taxed twice. In Norway, dividends are tax exempt at the shareholder level and a refund of corporate tax on distributed earnings is not motivated. However, the Norwegian tax code attempts to refund corporate tax on retained earnings by allowing shareholders to raise the cost basis by the accumulated retained earnings over the holding period. If the stock price appreciates at the same rate as the retained earnings, there is no tax liability on capital gains. The second objective of our paper is to investigate how the tax treatment of taxed domestic investors visavis tax-exempt domestic investors and foreign investors influences return and volume patterns around the distribution of the capital-gains-tax credit.[2]

[1] A taxable foreign shareholder may offset the Norwegian withholding tax against home-country income tax, but tax-exempt foreign shareholders cannot claim the offsetting foreign tax credit. Some tax treaties allow tax-exempt foreign shareholders to file with the Norwegian tax authorities for an exemption from withholding tax. Our analysis is based on the assumption that foreign shareholders must pay tax either in Norway or in their home country.

[2] Norwegian mutual funds are not taxed, but collect and pass through the capital-gains-tax credit to mutual fund owners. When the owner of the mutual fund sells shares in the fund, he can use the tax credit to reduce tax liability on the price appreciation of the mutual fund shares.

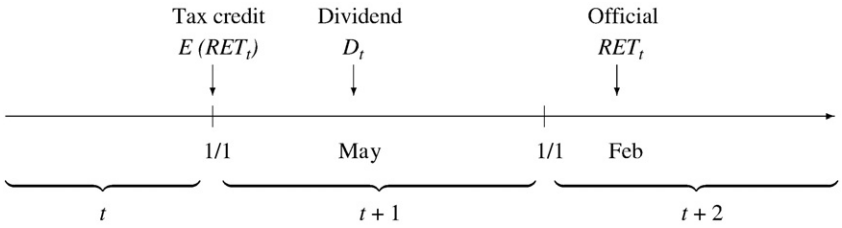

Fig. 1. Time line: Distribution of the tax credit for corporate income from year t, distribution of the dividend D_t in year $t+1$, and announcement of the step-up amount RET_t in February year $t+2$.

2.1. Basis adjustment

Fig. 1 presents a time line of events. The books for corporate income year t close in December.[3] The tax credit is distributed over the turn of the year and shareholders who own the shares at this time receive the right to step-up the cost basis. The step-up amount is unknown at this time. A few months later, the annual dividend for corporate income year t is approved by the general meeting and paid to shareholders. Afterwards, the tax authorities examine the corporate tax return for corporate income year t, determine the retained earnings, and announce the official step-up amount RET_t in February year $t+2$. The capital gains tax calculation for the shareholder depends on when he purchases and sells the shares.

2.1.1. General rule

Consider a shareholder who purchases the shares at price P_t in year t before the distribution of the tax credit RET_t. The shareholder holds the shares over k tax-credit distributions and k dividend payments. The shareholder sells the shares at price P_{t+k} in year $t+k$. The Norwegian tax code states that the shareholder must report a capital gain in his tax return for personal income year $t+k$ computed as:

$$G_{t+k} = P_{t+k} - \left(P_t + \sum_{s=t}^{t+k-1} RET_s \right), \quad k \geq 1. \tag{1}$$

For simplicity, we ignore transaction costs which also enter the capital gains calculation. The general rule assumes that a shareholder who receives the tax credit of corporate income year t also earns the dividend of that year. The Norwegian tax code provides two dividend correction rules for transactions that take place between the distribution of the tax credit and the payment of the dividend.[4]

2.1.2. Dividend correction rule I

Consider a shareholder who *sells* the shares in year $t+k$ after the distribution of the tax credit for the previous corporate income year $t+k-1$ but before the payment of the dividend for year $t+k-1$. The shareholder must *add* the last dividend (that he does not earn) to his basis:

$$G_{t+k} = P_{t+k} - \left(P_t + \sum_{s=t}^{t+k-1} RET_s + D_{t+k-1} \right), \quad k \geq 1. \tag{2}$$

2.1.3. Dividend correction rule II

Next, consider a shareholder who *purchases* the shares in year $t+1$ after the distribution of the tax credit for corporate income year t but before the payment of the dividend for year t. The shareholder must *subtract* the first dividend from his basis:

$$G_{t+k} = P_{t+k} - \left(P_{t+1} + \sum_{s=t+1}^{t+k-1} RET_s - D_t \right), \quad k \geq 2. \tag{3}$$

The application of this rule to the special case of $k=1$ is explained in Section 2.2 below (dividend capture).

2.1.4. Transactions between distributions

If the shareholder purchases the shares after the distribution of the tax credit and sells it before the payment of the dividend the same year, there is no basis adjustment and the capital gain is simply the difference between the sell and the purchase prices. This is also the case when the shareholder purchases the shares after the payment of the dividend for corporate income year t and sells the shares before the distribution of the tax credit for corporate income year $t+1$.

[3] The fiscal year ends in December for all firms.

[4] The two dividend correction rules apply to distributions of tax credits and dividends that take place in 1997–2006. In 1994–1996, the dividend corrections are capped such that adding the dividend in Eq. (2) must not increase or lead to a tax-deductible capital loss, and subtracting the dividend in Eq. (3) must not decrease or lead to a taxable capital gain. In 1992–1993, the dividend correction rules do not apply.

Eq. (1) captures the essence of the Norwegian imputation-tax system: the tax credit comes in the form of a right to step-up the basis by the sum of retained earnings over the holding period. On average in a large portfolio and over long holding periods, the expected capital gain is zero and corporate income is taxed only at the corporate level. Intentionally, the imputation-tax credit works only on average. Taxable gains and losses may result from changes in expectations about profits and losses. Such speculative gains are subject to double taxation, first at the shareholder level when the shareholder sells the shares, and then at the corporate level when the firm realizes the earnings associated with the capital gain. In this way, the Norwegian tax code accomplishes the dual objective of taxing average income only at the corporate level and, at the same time, taxing speculative gains twice. The first dividend correction rule (Eq. (2)) shields the shareholder from tax liability brought by selling the shares at a high cum-dividend price. The second dividend correction rule (Eq. (3)) makes sure that the shareholder cannot create a tax-deductible capital loss by purchasing the shares at the higher cum-dividend price.

The step-up amount can be negative, for example, when a company with zero earnings for income year t pays a dividend $D_t > 0$. A shareholder who purchases the shares before the distribution of the tax credit and sells them after the payment of the dividend must report a capital gain in his personal tax return equal to:

$$G_{t+1} = P_{t+1} - (P_t - RET_t). \tag{4}$$

If the purchase price is $P_t = 100$, the dividend $D_t = 10$, and the sell price $P_{t+1} = 90$, the reported capital gain is zero and the shareholder has no tax liability. Hence, the dividend does not generate personal tax liability. Corporate losses do not generate personal tax liability. Corporate earnings are defined by the corporate tax return and cannot be negative. Corporate losses can be carried forward but not carried back. The step-up amount is negative if the firm pays a dividend that exceeds the (non-negative) income reported on the corporate tax return.

2.2. Short-term trading

The gain and loss calculations related to short-term trading are simple. Let P^c denote the purchase price immediately before respective distribution and P^e the sell price immediately after. The determination of those prices is the objective of Section 3 below.

2.2.1. Tax-credit capture

Consider a shareholder who purchases the shares cum-credit and sells them ex-credit, and suppose that the shareholder does not receive the subsequent dividend. Then, according to the dividend correction rule (Eq. (2)), the shareholder must report a capital gain equal to:

$$G_{t+1} = P^e_{t+1} - (P^c_t + RET_t + D_t). \tag{5}$$

The step-up amount equals the earnings per share $Y_t = RET_t + D_t$ for corporate income year t.[5] It influences the capital gain reported on the shareholder's tax return for personal income year $t+1$. The step-up amount is unknown at the time of the tax-credit capture. The dividend D_t is paid to shareholder in year $t+1$, and the official RET_t is announced in February year $t+2$ (see Fig. 1). Uncertainty has been resolved when the shareholder reports his tax return for personal income year $t+1$, which is due in April year $t+2$.

2.2.2. Dividend capture

Consider a shareholder who purchases the shares cum-dividend and sells them ex-dividend. Since he is not entitled to the tax credit, according to the dividend correction rule (Eq. (3)), the shareholder must report a capital gain for personal income year $t+1$ equal to:[6]

$$G_{t+1} = P^e_{t+1} - (P^c_{t+1} - D_t). \tag{6}$$

2.3. Legal risk

The Norwegian tax code contains a general provision against transactions which serve no other business purpose than tax avoidance. In the context of tax credit and dividend capture, the tax authorities may decide whether a transaction has taken place for tax purposes and nullify either the buy or the sell transaction. The decision to nullify a transaction is made by the officer at the local tax office where the shareholder files his tax return. The decision is subjective and based on the volume of trade, the time that elapses between the buy and the sell transactions, and whether the position is hedged. The Norwegian tax authorities have no jurisdiction over tax-exempt domestic shareholders or foreign shareholders. Therefore, in transactions between a taxed domestic shareholder and either a tax-exempt domestic shareholder or a foreign shareholder, the legal risk is borne by the domestic taxed shareholder. If the tax avoidance is substantial, the tax-exempt domestic shareholder may be charged for help with tax fraud.

The provision against tax evasion has been invoked during the time period we study, and we investigate its effect on price formation and volume. Following the newspaper coverage of unusual trading around the ex-dividend day of certain large stocks in

[5] The first year, 1993, the step-up amount is *RET* and, the three subsequent years, 1994–1996, it is min(*Y*,0) if $RET < 0$, and *RET* if $RET \geq 0$.

[6] The first two years, 1992 and 1993, when the dividend correction rules do not apply, the capital gain is $G = P^e - P^c$ and the dividend capturer earns a tax credit for the capital loss that he incurs from holding the shares over the ex-dividend day.

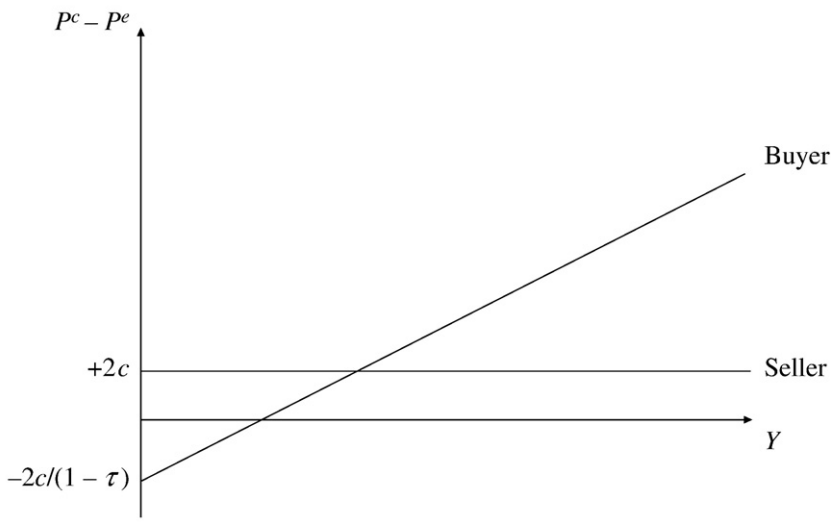

Fig. 2. Reservation prices for the tax credit: P^c is the negotiated purchase price cum-credit, P^e is the negotiated sell price ex-credit, Y is the step-up amount, τ is the marginal tax rate on capital gains, and $2c$ is the round-trip transaction cost.

May 1998, the tax authorities audited leading banks and brokerage firms. Based upon their investigation of sizable transactions between foreign institutional shareholders and domestic banks, the tax authorities decided to nullify certain transactions and demanded that the domestic banks pay the avoided withholding taxes along with fines.

3. Costly-arbitrage model

3.1. Tax-credit capture

A potential buyer of the tax credit meets with a potential seller, and they bargain over the gains from trade. The buyer can use the step-up amount $Y = RET + D$ to shield taxes at rate τ. The seller is a tax-exempt shareholder, who cannot use this right. The tax credit is physically attached to ownership of the shares, so the transfer of a tax credit requires that the buyer purchases the shares from the seller and holds onto them over the distribution of the tax credit. An agreement can be arranged such that the buyer purchases the shares at the cum-credit price P^c and promises to sell them back at the ex-credit price P^e. The negotiated price difference $P^c - P^e$ is a capital gain to the seller and a capital loss to the buyer and defines how much the buyer pays for the tax credit. We make the following specific assumptions:

Assumption 1. The step-up amount is known, i.e., we ignore that actual market participants can only estimate earnings per share $E(Y)$ with error.

Assumption 2. There is no legal risk, i.e., we assume that the provision against tax evasion is ineffective.

Assumption 3. The agreement locks in prices P^c and P^e. The agreement isolates the buyer from price risk.

Assumption 4. The cash flows from the tax credit are earned at the time of trade, i.e., we ignore discounting.

Assumption 5. For each transaction, each party pays a transaction cost c. In order to keep the positions of the buyer and the seller symmetric, we define the transaction cost after tax.

The first three assumptions imply that the transaction is risk free for the buyer and the fourth assumption that the purchase is fully financed.

The buyer is willing to purchase the tax credit if the tax saving exceeds the sum of the capital loss and the transaction costs:

$$(P^e - P^c)(1-\tau) - 2c + \tau Y \geq 0. \tag{7}$$

The first term is the buyer's capital loss after tax, the second term the transaction cost, and the third term the tax credit. The seller is willing to supply the tax credit if the capital gain exceeds his transaction costs:

$$P^c - P^e - 2c \geq 0. \tag{8}$$

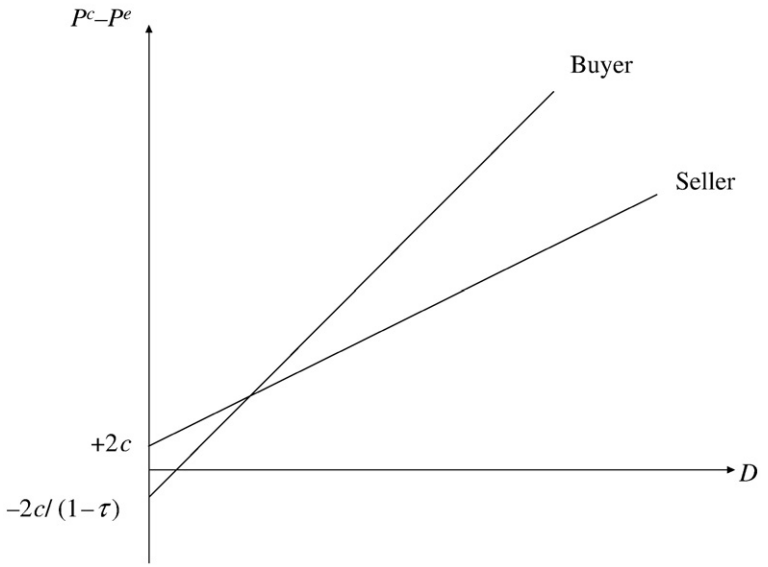

Fig. 3. Reservation prices for the dividend: D denotes the dividend, τ the capital gains tax rate, and $2c$ the round-trip transaction cost.

We obtain the gains from trade by adding Eqs. (7) and (8):

$$-4c + \tau Y + \tau(P^c - P^e) \geq 0. \tag{9}$$

The gains from trade are endogenous and depend on how they are divided because the negotiated capital loss shields taxes in addition to the basis adjustment. The two reservation price Eqs. (7) and (8) are displayed in Fig. 2. A transaction takes place when the buyer's valuation exceeds that of the seller, which occurs to the right of the intersection of the two lines. Otherwise, to the left of the intersection, the parties do not trade. The supply of tax credits is limited to the number of shares held by tax-exempt shareholders, while the demand for tax credits is limited only to the extent that there are less expensive ways to shield taxable income.[7]

Bertrand competition among buyers implies that sellers capture the gains from trade and that Eq. (7) holds with strict equality:

$$P^c - P^e = -\frac{2c}{1-\tau} + \left(\frac{\tau}{1-\tau}\right) \times Y. \tag{10}$$

3.2. Dividend capture

The sequence of arguments is similar. A potential buyer meets with a potential seller, and they bargain over the gains from trade. The buyer is a domestic shareholder who must pay tax at rate τ on trading profits, but is exempt from tax on dividends. The seller is a foreign shareholder who is exempt from tax with the exception of a withholding tax on the dividend at rate τ_w. The dividend is physically attached to the shares, so avoiding the withholding tax requires that the buyer purchases the shares cum-dividend and sells them back ex-dividend. An agreement means that the buyer purchases the shares at the cum-dividend price P^c and promises to sell them back at the ex-dividend price P^e. The negotiated price difference is a capital gain to the seller and a capital loss to the buyer. The latter covers his loss with the cash dividend. We make the analogous Assumptions 1–5 above to ensure that the dividend capture is risk free for the buyer and fully financed.

The buyer is willing to purchase the dividend if its value exceeds the capital loss and the transaction costs:

$$(P^e - P^c) - \tau[P^e - (P^c - D)] - 2c + D \geq 0. \tag{11}$$

This expression invokes the dividend correction rule (Eq. (3)). The seller is willing to supply the shares if the capital gain exceeds the after-tax value of the dividend and the transaction costs:

$$P^c - P^e - 2c - (1 - \tau_w)D \geq 0. \tag{12}$$

[7] Since the tax credits are attached to physical ownership of shares, short sellers cannot increase the supply of tax credits beyond the tax credits attached to the number of shares held by tax-exempt investors.

The two reservation prices are shown in Fig. 3. Trade takes place to the right of the intersection, where the buyer values the dividend higher than the seller. Bertrand competition among potential buyers implies that sellers capture the gains from trade and that Eq. (11) holds with strict equality:

$$P^c - P^e = -\frac{2c}{1-\tau} + D. \tag{13}$$

Neither tax rate influences the marginal value of the dividend as a result of the dividend correction rule (Eq. (3)) and competition among buyers.

4. Empirical analysis

4.1. Data

We collect data for listed Norwegian stocks in 1992–2005. Daily closing transaction prices, the number of shares traded, the stock market index and the dividend per share D are taken from the Oslo Stock Exchange. The amount of the step-up per share *RET* is taken from the official website of the Norwegian tax authorities. The full data set consists of 1976 firm-years. We require that a stock is traded on the last day before the distribution as well as the first day after. This sampling procedure biases the analysis in favor of the costly-arbitrage model as we focus on the more liquid stocks. Subject to this sample selection criterion, the final sample consists of 1285 ex-credit observations and 652 ex-dividend observations.

We also purchase ownership data for a subset of firms with positive tax credits and dividends in 1997–1999. This data set allows us to investigate the type of investors who are trading around the distributions as well as whether changes in ownership are temporary. Listed Norwegian stocks are kept as book entries in the official share registry. Domestic shareholders must register by name and address, while foreign shareholders can choose whether to register directly or in the name of a custodian bank (street name). Daily ownership balances using a window of 30 business days around each distribution are obtained. To protect shareholder identities, the ownership data are aggregated into 32 sectors according to the classification system of Statistics Norway. Each record of the data contains the date, a security identification code, a sector identification code, the aggregate number of shares held by the sector, and the total number of shares outstanding.

4.2. Testing methodology

4.2.1. Prices

Following the methodology in McDonald (2001), we estimate the regression model:

$$\frac{P^c - P^e}{P^c} + r_m = a + b \cdot \frac{Y}{P^c} + c \cdot PAST + e, \tag{14}$$

where P^c is the last transaction price cum-credit, P^e is the first transaction price ex-credit, r_m is the realized market return from the last business day cum-credit to the first business day ex-credit, Y/P^c is the step-up yield, and *PAST* is the average daily return during the past calendar year. The data include two types of securities: common stocks issued by corporations and preferred stocks issued by savings banks. For preferred stocks, we replace realized market return r_m with an estimate of "accrued interest". The latter is the product of the average annual dividend yield of all preferred stocks and the number of calendar days between the last business day cum-credit and the first business day ex-credit. The costly-arbitrage model (10) implies:

$$\begin{aligned} a &= -\frac{2c/P^c}{1-\tau} < 0, \\ b &= \frac{\tau}{1-\tau} = 0.389. \end{aligned} \tag{15}$$

These predictions are derived under the assumption that the discount rate is zero. In our data, the shareholder does not earn the cash flows from the tax credit before he files his tax return fourteen months after the tax-credit capture. With a positive discount rate, the predicted slope coefficient is below 0.389. For example, we expect that $b = 0.346$, if the continuously-compounded annual discount rate is 10%.

A large empirical literature has shown that stock returns are special around the turn of the year. Branch (1977) reports higher stock returns in the first week of January for stocks with poor past performance, and Keim (1983) and Reinganum (1983) show that stock returns are particularly high for small capitalization stocks. Furthermore, Sias and Starks (1997) find that stock returns are higher in stocks with less institutional ownership, and Grinblatt and Keloharju (2004) show that individuals increase loss-taking during the last eight business days of the calendar year. Following Roll (1983), we control for the turn-of-the-year effect by including the average daily return from the past year in the regression. Since we want to make inference from the magnitude of the intercept, we subtract the sample average from the variable PAST. We do not control for firm size because essentially all Norwegian stocks are small capitalization stocks, and we do not control for ownership by individuals or institutions because we do not have ownership data except in 1997–1999.

For the ex-dividend day, we estimate the corresponding regression model:

$$\frac{P^c - P^e}{P^c} + r_m = a + b \cdot \frac{D}{P^c} + e. \tag{16}$$

The costly-arbitrage model (13) implies:

$$\begin{aligned} a &= -\frac{2c/P^c}{1-\tau} < 0, \\ b &= 1. \end{aligned} \tag{17}$$

Both regression models (14) and (16) are estimated with ordinary least squares. To assess the impact of a possible change in legal risk, we also interact the yield variable with a dummy variable for the sample period before the tax audit in May 1998 and another for the sample period after the tax audit. The panel is highly unbalanced with mostly short time-series, so we ignore fixed-firm effects. Since the dependent variable is adjusted for stock market movements, which is equal for all firms, we make no further adjustments for fixed-time effects.

4.2.2. Trading volume

Tax-related trading around the ex-dividend day may result in higher than normal trading volume. We estimate the following two regression models with ordinary least squares:

$$ln(TO) = a + b \cdot \frac{Y}{P^c} + c \cdot PAST + e, \tag{18}$$

and

$$ln(TO) = a + b \cdot \frac{D}{P^c} + e, \tag{19}$$

where *TO* (turnover) is the number of shares traded divided by the number of shares outstanding over the time period −5 to +5 business days around the distribution. Tax arbitrage implies that $b \geq 0$. In the tax-credit regression, we control for the turn-of-the-year effect on trading volume by including *PAST*. The previous literature suggests that $c < 0$ (see Dyl, 1977). The regression models deviate from the literature in two important ways. First, we do not subtract expected turnover from observed turnover because turnover data are extremely skewed. Many stocks in our sample are very infrequently traded except around the two distributions. Therefore, we cannot accurately estimate expected trading volume using data from outside the event period. Second, for the same reason, we do not include variables which control for transaction costs and risk.[8] With low trading frequency, we cannot obtain reliable estimates of risk and transaction costs (e.g., bid-ask spread) using data from outside the event period. Due to skewness, we must interpret the volume regressions cautiously.

4.2.3. Changes in ownership

We develop a simple regression model of changes in stock ownership, which here is cast in terms of dividend capture. Consider a firm with N shares, price per share P^c, and dividend per share D. Foreign shareholders own the proportion $\theta_s = N_s = N$, where s denotes sellers. We assume that the supply of stocks cum-dividend is proportional to the dividends paid on the foreign-owned stocks:

$$P^c \Delta N_s = \beta D N_s, \tag{20}$$

where Δ denotes change and $\beta \geq 0$ is a proportionality constant. We divide both sides of the equation by firm size $N \times P^c$:

$$\Delta\theta_s = \beta\left(\frac{D}{P^c} \times \theta_s\right). \tag{21}$$

Finally, we add a constant term α, which picks up average trading volume unrelated to the payment of the dividend, and an idiosyncratic error term ε:

$$\Delta\theta_s = \alpha + \beta\left(\frac{D}{P^c} \times \theta_s\right) + \varepsilon. \tag{22}$$

The dependent variable is the change in the foreign stock ownership fraction from day −15 to day −1 cum-dividend. To find out whether the foreign ownership position reverts after the payment of the dividend, we estimate a second regression where the dependent variable is the change in the foreign stock ownership fraction from day 0 to day +14 ex-dividend. We expect that the slope coefficients are negative cum-dividend and positive ex-dividend, and that they sum to zero.

[8] See, e.g., Lakonishok and Vermaelen (1986)), Michaely and Vila (1996), and Dhaliwal and Li (2006).

Table 1
Price and volume variables.

	Mean	Std	Min	Max	#Obs
A. Tax credit					
Price drop	−0.013	0.059	−0.502	0.240	1285
Step-up yield	0.028	0.071	−0.624	0.524	1285
Turnover	0.055	0.090	0.000	2.028	1285
B. Dividend					
Price drop	0.039	0.068	−0.162	0.722	652
Dividend yield	0.043	0.055	0.001	0.765	652
Turnover	0.040	0.063	0.000	0.995	652

The price drop is the cum-distribution price minus the ex-distribution price divided by the cum-distribution price. For common stocks we add the stock market return over the event window (three to five days for the tax credit, depending on the year, and one to three days for the dividend), and for preferred stocks the accrued interest computed as the sample average dividend yield times the number of days over the distribution. Step-up yield is the step-up amount divided by the cum-distribution price, and dividend yield is the dividend amount divided by the cum-distribution price. Turnover is the number of shares traded over the event window −5 to +5 business days around the distribution over the number of outstanding shares.

The ownership data are aggregated into 32 sectors. The sellers are identified as the foreign sector. The buyers are found among the 31 domestic sectors. We search the data for active and inactive participants in the tax arbitrage by estimating the regression Eq. (22) for each domestic sector. The dependent variable is the change in the sector's stock ownership fraction from day −15 to day −1 in the cum-dividend regression, and from day 0 to day +14 in the ex-dividend regression. For active participants, we expect that the slope coefficients are positive cum-dividend and negative ex-dividend, and that they sum to zero.

To conclude, we are interested in four slope coefficients:

$$\beta = \{\beta_s^c, \beta_s^e, \beta_b^c, \beta_b^e\}, \tag{23}$$

where subindexes b and s denote buyers and sellers and superindexes c and e cum-dividend and ex-dividend, respectively. The buyer coefficients are aggregated across active domestic sectors. Dividend capture predicts:

$$\begin{aligned} &\beta_s^c < 0 \text{ and } \beta_s^e > 0. \\ &\beta_b^c > 0 \text{ and } \beta_b^e < 0. \end{aligned} \tag{24}$$

If the change in ownership is temporary and ownership shifts back to its original level after the distribution, we must have:

$$\begin{aligned} &\beta_s^c + \beta_s^e = 0. \\ &\beta_b^c + \beta_b^e = 0. \end{aligned} \tag{25}$$

Finally, since buyers and sellers interact, the sum of buyer and seller coefficients must add to zero:

$$\begin{aligned} &\beta_s^c + \beta_b^c = 0. \\ &\beta_s^e + \beta_b^e = 0. \end{aligned} \tag{26}$$

A corresponding set of regression Eq. (22) and restriction Eqs. (23)–(26) can be derived for the tax-credit capture event. The tax-exempt ownership fraction replaces the foreign ownership fraction, and the step-up yield Y/P^c replaces the dividend yield D/P^c.

Table 2
Ownership structure.

A. Taxed shareholders		B. Tax exempt		C. Unknown tax	
Corporations [a]	17.6%	Public sector	22.0%	Foreign	30.1%
Individuals [b]	8.9%	Mutual funds	7.7%	Unclassified	0.1%
Banks [c]	2.6%	Life insurance	4.7%		
Non-life insurance	1.0%	Pension funds	3.6%		
Non-profits [d]	0.9%	Charities [d]	0.8%		
Sum	31.0%		38.8%		30.2%

The table shows the value-weighted average stock ownership in the beginning of December 1999. The sector codes are from Statistics Norway.
[a] Corporations and other for-profit organizations.
[b] Individuals, partnerships, and sole proprietorships.
[c] Commercial banks, savings banks, financing companies, and financial holding companies.
[d] Charitable non-profit organizations are tax exempt. Other non-profit organizations pay taxes.

Table 3
Price regressions.

	A. Tax credit		B. Dividend	
Intercept	−0.0173	−0.0175	−0.0039	−0.0045
	(0.0018)	(0.0018)	(0.0021)	(0.0023)
Yield	0.137		0.991	
	(0.019)		(0.030)	
Pre-audit × yield		0.201		1.039
		(0.021)		(0.046)
Post-audit × yield		0.110		0.979
		(0.023)		(0.029)
Past return	1.484	1.469		
	(0.625)	(0.623)		
t-test difference		3.3		1.3
R^2	0.036	0.038	0.635	0.635
#Obs	1285	1285	652	652

Ordinary least squares regressions of the price drop on step-up yield (tax credit) and dividend yield (dividend), respectively, dummy variables for the time period before and after the tax audit, and the average daily return over the previous year. We have subtracted the sample average from the past return variable. The market return has been added to the price drop for common stocks, and accrued interest to the price drop for preferred stocks. Robust standard errors are reported below the coefficients. The *t*-statistic tests the hypothesis that the slope coefficients are equal before and after the tax audit.

4.3. Descriptive statistics

Table 1 reports summary statistics for the price and volume variables. We observe that the average market-adjusted price drop over the distribution of the tax credit is negative, implying that expected returns over the turn of the year are positive despite the distribution of the tax credit. It appears that the turn-of-the-year effect dominates the tax-credit effect. We also notice that the average step-up yield is 2.8%, which is substantially smaller than average return on equity (ROE). The basis adjustment is positive in 654 cases, zero in 521 cases, and negative in the remaining 110 cases. When the basis adjustment takes the value of zero, it is either because the firm is sheltered from corporate tax with loss deductions or large depreciations (the latter is notable in the offshore sector), or because its income is exempted from corporate tax (which is the case for Norwegian shipping companies). The extreme negative step-up yield of −62.4% is an artifact of dividing lagged book income with a low stock price as a result of corporate default. The extreme positive step-up yield is 52.4%. Large tax credits are often associated with the preferred stocks issued by savings banks (see Section 4.6 below). As reported in Panel B, the average market-adjusted price drop is 3.9%, less than the average dividend yield 4.3%. As a result, the price drop divided by the dividend is less than one, consistent with the extant ex-dividend day literature. The extreme dividend yield is 76.5%.

Table 2 reports the ownership structure of Norwegian stocks in the beginning of December 1999. Taxed domestic shareholders own 31% and tax-exempt domestic shareholders 38.8%. The remaining 30.2% are held by foreign shareholders and a few domestic shareholders with unknown type. The largest sectors are non-financial corporations, the public sector (primarily the Government pension fund), and foreign shareholders. Mutual funds and private pension funds are relatively small. Individuals own 8.9% directly.

4.4. Regression results

The results of estimating regressions (14) and (16) are reported in Table 3. Starting with the tax-credit regressions, we see that the price drop increases with the step-up yield, but the slope coefficient is significantly smaller than 0.389. Discounting at reasonable rates does not reduce the benchmark near the observed slope coefficient. The slope coefficient is steeper before the tax

Table 4
Volume regressions.

	A. Tax credit		B. Dividend	
Intercept	−3.489	−3.496	−3.886	−3.968
	(0.037)	(0.037)	(0.059)	(0.071)
Yield	−0.663		0.084	
	(0.508)		(0.744)	
Pre-audit × yield		1.563		6.648
		(0.723)		(1.957)
Post-audit × yield		−1.590		−1.489
		(0.570)		(1.240)
Past return	−15.510	−16.043		
	(8.965)	(8.963)		
t-test difference		3.2		4.2
R^2	0.003	0.010	−0.001	0.036
#Obs	1285	1285	652	652

Ordinary least squares regressions of the log of stock turnover during the event window −5 to +5 business days around the distribution on step-up yield (tax credit) and dividend yield (dividend), respectively, dummy variables for the time period before and after the tax audit, and the average daily return over the previous year. Robust standard errors are reported below the coefficients. The *t*-statistic tests the hypothesis that the slope coefficients are equal before and after the tax audit.

Table 5
Ownership changes around the ex-dividend day.

		Intercept	Pre-audit	Post-audit	R^2	t-test
A. Ordinary least squares						
Foreigners	Cum	−0.0027 (0.0010)	−0.234 (0.117)	0.250 (0.151)	0.022	−2.7
	Ex	−0.0008 (0.0015)	0.286 (0.186)	−0.108 (0.150)	0.008	1.9
Corporations	Cum	0.0002 (0.0005)	0.251 (0.116)	0.009 (0.047)	0.088	2.3
	Ex	−0.0004 (0.0011)	−0.183 (0.178)	0.058 (0.098)	0.002	−1.4
Banks	Cum	0.0008 (0.0005)	0.136 (0.058)	−0.084 (0.039)	0.026	3.3
	Ex	0.0004 (0.0006)	−0.169 (0.101)	−0.027 (0.059)	0.025	−2.0
B. Restricted least squares						
Foreigners	Cum	0.0000	−0.430 (0.069)	0.011 (0.105)	−0.002	−3.5
	Ex	0.0000	0.317 (0.112)	−0.111 (0.171)	0.017	2.1
Corporations	Cum	0.0000	0.259 (0.053)	0.021 (0.081)	0.098	2.5
	Ex	0.0000	−0.184 (0.112)	0.044 (0.170)	0.013	−1.1
Banks	Cum	0.0000	0.170 (0.053)	−0.032 (0.080)	0.024	2.1
	Ex	0.0000	−0.133 (0.060)	0.067 (0.090)	0.035	−1.8

Panel A: Ordinary least squares estimation of the change in stock ownership between 15 business days before the ex-dividend day to one day before (cum), and the change in stock ownership between the ex-dividend day and fifteen business days after (ex). The independent variable is the dividend yield multiplied by the foreign ownership fraction 15 business days before the ex-dividend day, interacted with dummy variables for the time periods before and after the initial news about the (possible) tax audit on May 8, 1998. Robust standard errors are reported below the coefficients. There are 156 observations. The t-statistic tests the hypothesis that the slope coefficients are equal before and after the tax audit.
Panel B: Maximum likelihood estimation of a system of six seemingly unrelated regression equations with no intercept and the restriction that the slope coefficients of foreign shareholders, corporations, and banks sum to zero cum and ex, pre-audit and post-audit (four restrictions).

audit but nevertheless smaller than predicted by the costly-arbitrage model (15). The positive coefficient of the past return variable means that stocks with poor past performance have higher returns over the turn of the year. Turning to the dividend regressions, we find that the intercepts are negative and the slope coefficients are close to unity as predicted by the costly-arbitrage model (17). The slope coefficient is approximately equal to one both before and after the tax audit. Hence, the possible increase in legal risk after the tax audit does not seem to affect price formation.

Table 4 displays the results from regressions (18) and (19). Trading volume increases with both step-up yield and dividend yield before the tax audit, but the positive correlation disappears after the tax audit. The difference between the slope coefficients is statistically significant. The magnitude of the slope coefficient is larger for the ex-dividend day. Consistent with the previous literature, trading volume around the turn of the year is significantly larger for loser stocks (with negative past return) than winner stocks (with positive past return).

The results of estimating the ownership regressions Eq. (22) are found in Table 5. Ownership changes at the aggregate sector level are very noisy and we are able to detect statistically significant patterns only around ex-dividend days. We do not report any results of the tax-credit distributions. Furthermore, we show changes in ownership in only three sectors: foreign shareholders (sellers), non-financial corporations (buyers), and banks (buyers). The results for all other sectors are statistically insignificant.

Panel A includes the ordinary least squares results. Robust standard errors are reported below the coefficients. We find that the intercept terms are small and mostly not significantly different from zero, that the pre-audit slope coefficients are statistically different from zero, and that the post-audit slope coefficients are not significantly different from zero. For foreign shareholders, the pre-audit slope coefficient is negative cum-dividend and positive ex-dividend, while these observations are reversed for corporations and banks. These patterns suggest that foreign shareholders sell shares to domestic banks and corporations cum-dividend and buy back the shares ex-dividend. Since the absolute magnitudes of the coefficients are about the same, we also conclude that the changes in ownership are temporary in accordance with restriction Eq. (25). Statistical tests cannot reject the hypothesis that the slope coefficients cum and ex-dividend sum to zero (not reported). The statistical insignificance of all post-audit slope coefficients suggests that traders do not engage in tax-motivated trading after the tax audit. The t-statistics in the rightmost column show that the differences between the pre-audit and post-audit coefficients are statistically significant.

In Panel B, we report the results of estimating a system of six seemingly unrelated equations with no constant term and with the restriction Eq. (26) imposed on the slope coefficients, i.e., the slope coefficients of foreign shareholders, corporations, and banks sum up to zero for each combination of cum- and ex-distribution, pre-audit and post-audit (four restrictions). The restrictions cannot be rejected (test statistic not reported). The slope coefficients suggest that foreign shareholders sell to domestic shareholders of which corporations pick up 60% ($\approx$0.259/0.43) and banks 40% ($\approx$0.17/0.43). These estimates enable us to assess the amount of shares which are traded for tax purposes. We multiply the average dividend yield 4.2% with the foreign ownership fraction 30% and the pre-audit slope coefficient of foreign shareholders −0.43 to conclude that 0.55% of the outstanding shares are temporarily transferred to Norwegian banks and corporations to avoid the withholding tax on dividends.

In comparison with the previous literature on ex-dividend day trading, the estimate of 0.55% is quite large. For example, Michaely and Vila (1996) show that abnormal trading volume around the ex-dividend day averages to 0.16% of the shares. Dividing this number by two (cum and ex), we conclude that only 0.08% of the shares have changed hands around the ex-dividend day in the United States. However, in comparison with the foreign ownership fraction of 30% of Norwegian stocks (see Table 2 above), the

Table 6
Simulation results.

	Intercept	Slope	R^2
A. True parameters	−0.0172	0.3889	N/A
B. Estimated parameters			
$\sigma_u = 0.000$	−0.0172	0.3891	0.233
$\sigma_u = 0.025$	−0.0160	0.3467	0.207
$\sigma_u = 0.050$	−0.0136	0.2600	0.156
$\sigma_u = 0.075$	−0.0114	0.1843	0.110
$\sigma_u = 0.100$	−0.0100	0.1302	0.078
$\sigma_u = 0.125$	−0.0089	0.0942	0.058

Panel A shows the true parameters and Panel B the average estimated parameters from 500 simulations. The simulations are based on the 1285 observed values of the step-up yield. The dependent variable is generated by the parameters in Panel A plus a normally distributed error term chosen such that the standard deviation of the dependent variable equals the observed standard deviation 0.057. σ_u is the standard deviation of a normally distributed estimation error which is added to the independent variable.

point estimate 0.55% is quite small and suggests that static tax-clientele models such as Brennan (1970) and Allen et al. (2000) may have predictive power despite that shareholders with different marginal tax rates can trade around the ex-dividend day.

4.5. Errors-in-variable bias

The evidence in Table 3 rejects the costly-arbitrage model of price formation around the distribution of the tax credit because the regression slope coefficient is too small. One possible explanation is that the slope coefficient is negatively biased. The regression model (14) assumes that shareholders observe the step-up yield without error while, in fact, shareholders must trade on earnings-per-share forecasts. We assess the magnitude of the bias with simulations.

Based on the sample of observed step-up yields Y/P^c, we generate the dependent variable $\hat{y}$ from the estimated intercept in Table 3, the theoretical slope parameter, and a normally distributed error term e:

$$\hat{y} = -0.0172 + 0.389\frac{Y}{P^c} + e. \tag{27}$$

The scale of the error term is chosen such that the standard deviation of $\hat{y}$ approximates the observed standard deviation of the dependent variable $(P^c - P^e)/P^c$. We estimate the regression parameters using the generated data and report the average regression parameters across 500 simulations. Then, we repeat the regressions, adding a normally distributed error term u with mean zero and standard deviation σ_u to the independent variable: $Y/P^c + u$. The simulation results are reported in Table 6. Panel A reports the true parameters and Panel B the average estimated parameters with different magnitudes of the error term. Apparently, the average estimated parameters are close to the true parameters when there is no error. We also see the errors-in-variable bias which increases with the standard deviation of the error term.

To assess the magnitude of the forecast error σ_u, we collect the last earnings-per-share forecast for the current income year for the subset of mostly large firms which are covered by I/B/E/S in 1995–1999. Shipping, offshore, and the preferred stocks issued by savings banks are eliminated (64 observations) because financial and tax reporting are very different. For the remaining sample of 153 firm-years, we compute the forecast error as the I/B/E/S earnings-per-share forecast minus the realized step-up yield Y/P and divide this difference by the last stock price before the distribution of the tax credit. The standard deviation of the forecast error is 0.073. In fact, this forecast error is worse than using the in-sample unconditional average to forecast the step-up amount (the standard deviation of Y/P^c is 0.071). The forecast error is large because I/B/E/S forecasts are generated for stock valuation purposes and not for tax-credit capture. I/B/E/S forecasts ignore important differences between financial and tax reporting. The standard deviation of the forecast error is highly influenced by a few large observations, which are likely to reflect accounting practices rather than genuine uncertainty. If we eliminate the four largest errors in each tail of the distribution (5% of the sample), the standard deviation of the I/B/E/S forecast error drops to 0.053, and if we eliminate eight observations in each tail (10% of the sample), it drops further down to 0.042. We see in Table 6 that a forecast error of 0.075 implies a slope coefficient of 0.1843 and that a forecast error of 0.0500 raises the slope coefficient to 0.2600. Arbitrageurs can do much better than using I/B/E/S forecasts. Therefore, we conclude that errors-in-variable bias is unlikely to account for the rejection of the costly-arbitrage model.

4.6. Event study of preferred stocks

Preferred stocks issued by Norwegian savings banks are debt-like securities with a claim on the annual dividend, but with no claim on the retained earnings. Nevertheless, a loophole in the tax code allows preferred shareholders to claim an imputation-tax credit for retained earnings. In September 2000, the Government eliminates the tax credit to preferred shareholders. Fig. 4 plots the average cumulative return for 21 preferred stocks around the announcement of the proposed tax law change on August 15 and the final approval by the Parliament on September 6. The market value of preferred stocks decreases by 10.5% between these two

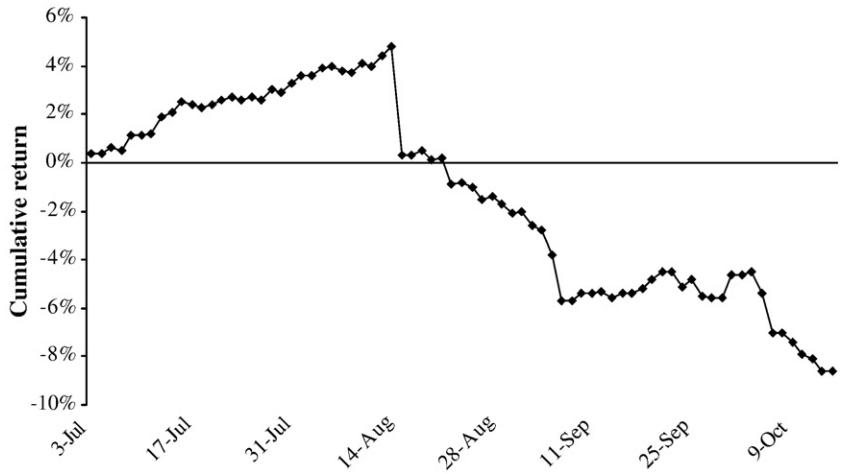

Fig. 4. Market reaction to the elimination of tax credits to preferred stocks. Equally-weighted average, cumulative return of 21 preferred stocks around the announcement of a change in the tax code that eliminates future imputation-tax credits for preferred stocks.

dates. This is an estimate of the market value of future imputation-tax credits attached to preferred stocks. The estimate is large and reflects that the average realized step-up yield for preferred stocks in 1993–2000 is 20%.[9]

5. International evidence and future research

We have found that the costly-arbitrage model of price formation is consistent with observed return patterns around the ex-dividend day in Norway, but that the model cannot explain the return patterns around the distribution of the tax credit. How general are these results? This section provides a survey of the international evidence on the parameters of the costly-arbitrage model.

Boyd and Jagannathan (1994) estimate the cross-section regression model:

$$\frac{P^{c} - P^{e}}{P^{c}} = a + b \cdot \frac{D}{P^{c}} + e. \tag{28}$$

Their model predicts that:

$$\begin{array}{l} a < 0 \text{ and } b = 1, \text{ if arbitrageurs are net buyers,} \\ a > 0 \text{ and } b = 1, \text{ if arbitrageurs are net sellers.} \end{array} \tag{29}$$

These predictions are based on the assumption that arbitrageurs are tax neutral and risk neutral.

Elton and Gruber (1970) can be regarded as a special case where shareholders have sorted themselves into tax clienteles, there are no arbitrageurs, and trading takes place only for liquidity purposes. Suppose there is a tax clientele with marginal tax rates on dividends and capital gains equal to τ_d and τ_g, respectively. The tax-clientele model predicts that the intercept is zero and the slope coefficient is positive:

$$a = 0 \text{ and } b = \frac{1 - \tau_d}{1 - \tau_g} > 0. \tag{30}$$

If the marginal tax rates are known, a test on the slope coefficient is also permissible.

Michaely and Vila (1995) develop a model with risk averse shareholders which predicts that:

$$a < 0 \text{ and } b = \sum w\left(\frac{1 - \tau_d}{1 - \tau_g}\right) > 0. \tag{31}$$

[9] Norwegian savings banks are funded by non-traded equity, which is closely-held by the county where the bank is headquartered, and by preferred stocks which are traded in the stock market. In the calculation of the step-up amount per share, the retained earnings of the savings bank are divided by the number of preferred stocks, but the number of non-traded shares do not enter the per-share calculation. Therefore, the step-up amount per preferred share is artificially inflated.

Table 7
International evidence.

	Intercept	Slope	Dividend	#Obs	Reference
A. Cash dividends					
United States	−0.002	0.977	1.000	132,057	Boyd and Jagannathan (1994)
Hong Kong	−0.011	0.972	1.000	1141	Frank and Jagannathan (1998)
Norway	−0.004	0.991	1.000	652	This paper
B. Lottery bonds					
Sweden	−0.003	1.432	1.000	267	Green and Rydqvist (1999)
Denmark	+0.010	1.180	1.000	485	Florentsen and Rydqvist (2002)
C. Tax credits					
Germany	−0.006	1.258	1.429	245	McDonald (2001)
Australia	−0.004	1.361	1.562	106	Partington and Walker (2002)
United Kingdom	−0.004	1.058	1.250	274	Bell and Jenkinson (2002)
Finland	−0.011	1.178	1.389	672	Rantapuska (2006)
Norway	−0.017	0.137	0.389	1285	This paper

The table shows the coefficients from regressing the percentage price change over the ex day on the dividend yield (Panel A), coupon yield (Panel B), and the dividend plus imputation-tax credit yield (Panel C), respectively. The dividend column shows the pre-tax value of a one-dollar dividend for a domestic shareholder.

The negative intercept captures a risk premium which compensates shareholders for unbalancing their portfolios over the ex-dividend day. The slope coefficient is a weighted average of shareholders' relative tax preferences, where the weight w depends on shareholders' wealth and risk tolerance.

Table 7 summarizes the results of studies which estimate regression model (28). We omit studies which report only the ratio of the price drop over the dividend.[10] The papers are sorted into studies of dividends (Panel A), lottery bonds (Panel B), and imputation-tax credits (Panel C). Within each panel, the papers are sorted by date. The column named "Dividend" contains the pre-tax value of a one-dollar dividend for a domestic shareholder. The pre-tax value is precisely one dollar in Panels A and B, but equals one dollar plus the tax credit in Panel C except in Norway where the dividend and the tax credit are paid on separate dates. The pre-tax value of a one-dollar dividend for a foreign shareholder is always one dollar because a foreigner cannot claim the imputation-tax credit. We leave out measures of statistical significance from the table as the parameter estimates across studies are persistent.

In Panel A, the intercepts are generally negative and the slope coefficients are close to one. The parameter estimates are consistent with the hypothesis that arbitrageurs buy shares cum-dividend and sell them ex-dividend as in Eq. (29). The negative intercepts reject the tax-clientele model (30).[11] In Panel B, the slope coefficients exceed one, which means that the marginal value of one-dollar coupon income exceeds one dollar. This is consistent with tax incentives. A short-term holder of a lottery bond over the ex-coupon day earns a package of a tax-free coupon payment and a tax credit for the capital loss he incurs over the ex-coupon day. However, slope coefficients above one are inconsistent with the costly-arbitrage model (29). Green and Rydqvist (1999) explain that tax-neutral arbitrageurs, who are indifferent between coupon income and capital gains, face short-sale constraints on lottery bonds. Finally, Panel C shows results of studies estimating the market value of imputation-tax credits. A general feature of these studies including our paper is that the slope coefficient falls below the pre-tax value of the dividend plus the tax credit.[12]

We conclude from the survey in Table 7 that the tax-clientele model (30) is rejected, that there is mixed evidence for the costly-arbitrage model (29), while the risk averse model (31) is consistent with the data. Uncertainty is, therefore, a natural candidate to explain the rejections of the costly-arbitrage model. McDonald (2001) suggests that arbitrageurs are unwilling to compete away the profits because they are concerned with the legal risk of holding a large position over the ex-dividend day. However, the finding that the Norwegian tax audit does not influence price formation speaks against the importance of legal risk. For Norway, we propose estimation risk. The cash flows of the tax credit are uncertain and must be estimated. The arbitrageur does not know the actual step-up amount until one year after the trade. The risk of miscalculating the step-up amount is diversifiable, but transaction costs for illiquid Norwegian stocks may prevent efficient diversification. Furthermore, evidence from lottery bonds suggests that diversification strategies may not always be so easy to implement in practice (see Green and Rydqvist, 1997).

Uncertainty can also create a financial problem. The arbitrageur incurs a certain capital loss over the distribution of the tax credit that he cannot recover until one year later. Given the uncertainty of the tax credit, the arbitrageur may have to finance the purchase cost (i.e., the capital loss) with equity. If the arbitrageur has limited equity for arbitrage positions, tying up scarce equity in the tax credit may prevent him from engaging in more profitable arbitrage opportunities later in the year. We propose this simple hypothesis for future research on the limits to arbitrage.

[10] Canada: Both and Johnson (1984), China: Milonas, Travlos, Xiao, and Tan (2002), Denmark: Jakob and Akhmedov (2005), Greece: Milonas and Travlos (2001), Italy: Michaely and Murgia (1995), Japan: Kato and Loewenstein (1995), New Zealand: Bartholdy and Brown (2001), and Sweden: Daunfelt (2002).

[11] Hong Kong is an interesting case with domestic shareholders tax exempt on investment income and participation by foreign shareholders prevented by a stamp duty. Frank and Jagannathan (1998) argue that the negative intercept rejects the costly-arbitrage model and develop a microstructure-based explanation instead.

[12] These results reject the costly-arbitrage model (29). McDonald (2001) and Cannavan et al. (2004) support this conclusion by estimating the market value of the imputation-tax credit using derivative prices in Germany and Australia, respectively.

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