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ABSTRACT

Investigation of the Costly-Arbitrage Model of Price Formation Around the Ex-Dividend Day*

We estimate the costly-arbitrage model of Boyd and Jagannathan (1994) 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 relate the difference in price formation to uncertainty.

JEL Classification: C78, D40, G10 and H26
Keywords: costly-arbitrage model, estimation risk, ex-dividend day, imputation-tax credit, legal risk and withholding tax

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1 Introduction

An extensive empirical literature documents abnormal stock returns over the ex-dividend day. Researchers have focused 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 the abnormal stock returns compensate arbitrageurs for transaction costs. Heath and Jarrow (1988), in turn, argue that arbitrageurs are risk averse and cannot take unlimited long or short positions. They suggest that the abnormal stock returns compensate arbitrageurs for excess risk taking. Lastly, Bali and Hite (1998) and Frank and Jagannathan (1998) propose microstructure-based arguments, which constitute 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 on two separate dates. The first date is the distribution of an imputation-tax credit, which compensates investors for capital gains taxes 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 rejects the costly-arbitrage model of price formation around the distribution of the tax credit, but we cannot reject the costly-arbitrage model for the ex-dividend day.

We examine the role of estimation risk. The cash flows from the imputation-tax credit are unknown at the time of the distribution and must be estimated. The cash dividend, on the other hand, is fixed in advance and known to all traders at the time of the distribution. The arbitrageur faces the risk of overestimating the value of the tax credit and, thus, overpaying for it. Estimation risk is diversifiable and can be avoided by purchasing a portfolio of stocks that carry tax credits. However, the different ex-day behaviors of stock returns around the two distributions suggest that diversifiable estimation risk matters. Trading volume is also affected. We observe significantly

higher trading volume around the ex-dividend day.

We also investigate the role of legal risk . The Norwegian tax authorities reserve the right to nullify transactions which serve no other business purpose 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 some of the largest banks and brokerage houses for excessive dividend capture. Before the tax audit, we find that foreign investors on average sell 0.55% of the outstanding shares to domestic banks (0.22%) and corporations (0.33%) prior to the ex-dividend day and re-establish their positions afterwards. After the audit, tax-related trading volume is negligible. However, stock return patterns are not affected by the tax 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, implying that listed firms do not fully capture the benefit of lowered cost of capital from the tax credit. This empirical result is consistent with several previous studies which estimate the market value of imputation-tax credits in other countries (see Table 1 below). Arbitrage also matters to tax authorities which design tax codes and collect taxes. The market response to the tax audit suggests that legal risk influences the volume of tax arbitrage and therefore tax revenues. Finally, arbitrage matters to investors who take the other side of the trade. The 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.

In Section 2, we relate our empirical results to the existing international evidence. We show that the different return patterns around the distribution of the dividend and the tax credit, respectively, are general across several studies. The rest of the paper reports the details of the Norwegian case study. Section 3 explains the relevant tax rules and Section 4 derives the hypotheses. The empirical analysis is carried out in Section 5, and Section 6 concludes.

2 International Evidence

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

$$\frac{P^c - P^e}{P^c} = a + b \cdot \frac{D}{P^c} + e \quad , \tag{1}$$

where P^c denotes the cum-dividend price, P^e the ex-dividend price, D the dividend, and e is a noise term. The costly-arbitrage model predicts that:

$$\begin{aligned} a < 0 \quad \text{and} \quad b = 1 \quad &, \text{if arbitrageurs are net buyers} \quad , \\ a > 0 \quad \text{and} \quad b = 1 \quad &, \text{if arbitrageurs are net sellers} \quad . \end{aligned} \tag{2}$$

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

The first paper by Elton and Gruber (1970) can be regarded as a special case where investors 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:

$$a = 0 \quad \text{and} \quad b = \frac{1 - \tau_d}{1 - \tau_g} > 0 \quad . \tag{3}$$

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 investors which predicts that:

$$a < 0 \quad \text{and} \quad b = \sum w \left(\tfrac{1-\tau_d}{1-\tau_g} \right) > 0 \quad . \tag{4}$$

The negative intercept captures a risk premium which compensates investors for unbalancing their portfolios over the ex-dividend day. The slope coefficient is a weighted average of investors' relative tax preferences, where the weight w depends on investors' wealth and risk tolerance. The slope coefficient can be different from one depending on parameter values.

Table 1 summarizes the results of studies which estimate regression model (1). We omit studies

which report only the price drop over the dividend ratio.[1] 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 number in the dividend column is the pre-tax value of a one-dollar dividend for a domestic investor. The pre-tax value is precisely one dollar in Panel 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 investor is always one dollar since she cannot claim the imputation-tax credit. We leave out measures of statistical significance from the table as the parameter estimates across studies are persistent.

Table 1: **International Evidence**

	Intercept	**Slope**	**Dividend**	**#Obs**	**Reference**
A. Dividend					
United States	−0.002	0.977	1.000	132,057	Boyd and Jagannathan (1994)
Hong Kong	−0.011	0.972	1.000	1,141	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 credit					
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	1,285	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 investor.

In Panel A, the intercepts are generally negative and the slope coefficients close to one. The

[1]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).

parameter estimates are consistent with the hypothesis that arbitrageurs buy stocks cum dividend and sell them ex dividend as in (2). The negative intercepts are inconsistent with the predictions of the tax-clientele model (3). Hong Kong is an interesting case. Domestic investors are tax exempt on investment income, while participation by foreign investors is prevented by stamp duty. Frank and Jagannathan (1998) think that the negative intercept rejects the costly-arbitrage model and develop a microstructure-based explanation instead.

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 she incurs over the ex-coupon day. However, slope coefficients above one are inconsistent with the costly-arbitrage model (2). Green and Rydqvist (1999) explain that tax-neutral arbitrageurs, who are indifferent between coupon income and capital gains, face short-sale restrictions on lottery bonds. The positive intercept in Denmark suggests that arbitrageurs are net sellers.

In Panel C, we can see the results of studies which estimate the market value of imputation-tax credits. A general feature of these studies is that the slope coefficient falls below the pre-tax value of the dividend plus the tax credit. These results are also inconsistent with the costly-arbitrage model (2). McDonald (2001) and Cannavan, Finn, and Gray (2004) confirm this conclusion using derivatives prices to estimate the market value of the imputation-tax credit in Germany and Australia, respectively.

We conclude from the survey in Table 1 that the tax-clientele model (3) is rejected, that there is mixed evidence for the costly-arbitrage model (2), and that the risk averse model (4), which puts the least restrictions on the data, is consistent with estimated parameters. Uncertainty is 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, long position over the ex-dividend day. Below, we investigate whether legal risk can explain the evidence from Norway. We shall also explore the role of estimation risk, although this source of uncertainty is specific to Norway and cannot explain any of the other

rejections in Panel C.

3 Tax Environment

This section explains the taxation of dividends and capital gains in Norway in 1992-2006. The taxation of dividends is simple. Dividends are tax free for all domestic investors, individuals and organizations, while foreign investors are subject to withholding tax. The first objective of our paper is to investigate the tax asymmetry between domestic and foreign investors. The withholding tax rate is 15% for OECD countries and 25% for most other countries. Sometimes, the foreign investor can offset the Norwegian withholding tax against home-country income tax, but tax-exempt foreign investors cannot claim the offsetting foreign tax credit. Some tax treaties allow tax-exempt foreign investors to file with the Norwegian tax authorities for an exemption from withholding tax.

The taxation of capital gains is complicated. Individuals and businesses are taxed at the 28% rate on realized capital gains. The tax rate is flat and does not depend on the time which elapses between the purchase and the sale of the stock. Tax-exempt organizations do not pay capital gains tax and foreign investors do not pay capital gains tax in Norway. The second objective of our paper is to investigate the tax asymmetry between investors that are subject to Norwegian capital gains taxes and investors that are not. 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 taxes from the firm and then give the corporate taxes back to investors 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 taxes is partial. The shareholders are given a tax credit for corporate taxes on dividends, while retained earnings that generate taxable capital gains for investors are taxed twice. The Norwegian tax code attempts the ambitious goal of a complete refund of corporate taxes. Dividends are tax-exempt. Capital gains are taxed, but investors can raise the cost basis to offset capital gains tax liability.

3.1 Cost-Basis Adjustment

The basis adjustment reduces tax liability when the investor sells the stock. The idea is to raise the investor's cost basis by the accumulated retained earnings over the investor's holding period. If the stock price appreciates at the same rate as the retained earnings, there is no tax liability on capital gains. Specifically, define:

$$\begin{aligned} B &= \text{book value of equity,} \\ Y &= \text{corporate net income,} \\ D &= \text{dividends,} \\ RET &= \text{retained earnings,} \\ r &= \text{cost of capital.} \end{aligned}$$

Suppose that book value of equity evolves over time as:

$$B_t = B_{t-1} + RET_t \quad . \tag{5}$$

The residual income model implies that the stock price at time t equals:

$$P_t = B_t + \sum_{s=t+1}^{\infty} \frac{E_t(Y_s) - rB_{s-1}}{(1+r)^{s-t}} \quad . \tag{6}$$

If we assume that there are no abnormal profits, which may be plausible in a large cross-section of firms and over long time periods, the terms in the summation are zero. In this case, an investor who purchases the stock year t and sells the stock year $t+k$ realizes a capital gain equal to:

$$G = P_{t+k} - P_t = \sum_{s=t+1}^{t+k} RET_s \quad . \tag{7}$$

The Norwegian tax code states that the investor must report a capital gain in her tax return for income year $t+k$ computed as:

$$G^{\tau} = P_{t+k} - \left(P_t + \sum_{s=t+1}^{t+k} RET_s \right) \quad , \tag{8}$$

where τ distinguishes the after-tax capital gain from the before-tax gain. For simplicity, we have ignored transaction costs which also enter the capital gains calculation. Equation (8) captures the essence of the Norwegian imputation-tax system: The tax credit comes in the form of a right to step up the cost basis by the sum of retained earnings over the investor's holding period. If prices evolve as in (7), the capital gain is zero, $G^{\tau} = 0$, and corporate income is taxed only at the corporate level. The formula works only on average. Taxable gains and losses may result from changes in expectations about abnormal profits and losses (the terms in the summation in (6)). Such speculative gains are subject to double taxation, first at the investor level, when the investor sells the stock, and then at the corporate level, when the firm realizes the abnormal earnings that generated the capital gain in the first place. In this way, the Norwegian tax code attempts to accomplish the dual objective of taxing average corporate income only at the corporate level and, at the same time, taxing speculative gains twice.

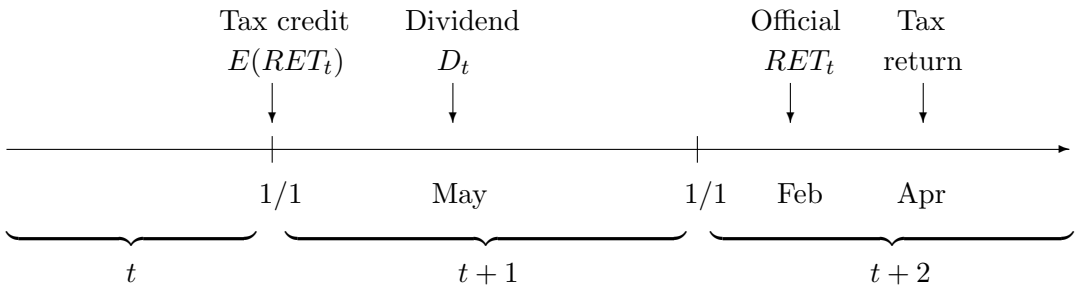

Figure 1: **Time Line**: Distribution of the tax credit for corporate income from year t, distribution of the dividend D_t during year $t+1$, and announcement of the step-up amount RET_t in February of year $t+2$. The personal tax return for income year $t+1$ is due in April $t+2$.

The books are closed once a year. For practical purposes, the right to the basis adjustment is also distributed once a year. See the time line in Figure 1. Corporate income from year t is realized. Investors who own the stock at the turn of the year receive the right to step up the cost basis. At this time, the step-up amount is unknown. A few months later, the annual dividend is approved by the annual general meeting and subsequently paid to investors. After the annual general meeting, the tax authorities examine the corporate tax return for year t, determine the corporate retained

earnings, and announce the official step-up amount RET_t in February year $t+2$. If the investor sells the stock in year $t+1$, she must report a capital gain or loss in his tax return. A capital loss can be fully offset against other income without limit. Hence, the investor benefits from the tax credit through reduced tax liability provided that she has taxable income to offset. The basis adjustment does not apply to tax-exempt domestic investors or foreign investors. Mutual funds are tax-exempt, but can collect and pass through the step-up amount RET_t to investors. The pass-through reduces tax liability when the investor sells shares in the fund.

The general rule (8) assumes that an investor who receives the tax credit RET_t also receives the dividend D_t. 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. First, consider an investor who *sells* the stock between the distribution of the tax credit and the payment of the last dividend. The investor must *add* the last dividend to her cost basis:

$$G^{\tau} = P_{t+k} - \left(P_t + \sum_{s=t+1}^{t+k} RET_s + D_{t+k} \right) = 0 \quad . \tag{9}$$

Next, consider an investor who *purchases* the stock between the distribution of the tax credit and the payment of the first dividend. The investor must *subtract* the first dividend from her cost basis:

$$G^{\tau} = P_{t+k} - \left(P_t + \sum_{s=t+1}^{t+k} RET_s - D_t \right) = 0 \quad . \tag{10}$$

The first correction (9) protects the investor from tax liability resulting from selling the stock at a high cum-dividend price, and the second correction (10) makes sure that the investor cannot generate a tax-deductible capital loss by purchasing the stock at the higher cum-dividend price. If the investor purchases the stock after the distribution of the tax credit and sells it before the payment of the dividend, there is no cost basis adjustment and the capital gain is simply the difference between the sell and the purchase price. The dividend correction rules (9) and (10) 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 (9) must not increase or lead to a tax-deductible capital loss, and subtracting the dividend in (10) must not decrease or lead to a

taxable capital gain. In 1992-1993, the dividend correction rules do not apply.

The general rule (8) implicitly assumes that corporate income is positive. This is ensured by the definition of corporate income by the tax return, which requires that $Y_t \geq 0$. Corporate loss can be carried forward, but it cannot be carried back. The step-up amount can be negative $RET_t < 0$, when the dividend exceeds the corporate income $Y_t < D_t$. In this case, the investor is compensated for tax liability through either the dividend or the dividend correction rule (9). Nevertheless, as we shall see in the data, negative tax credits can arise in parent-subsidiary relationships. The intercorporate dividend is taxable income for the receiver and tax deductible for the payer. If the subsidiary pays the parent a dividend which exceeds its taxable income for the year, corporate tax liability decreases and investor tax liability increases through a lower step-up amount which can be negative.

3.2 Short-Term Trading

The gain and loss calculation related to short-term trading is simpler. 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 4 below.

Tax-credit capture. Consider an investor who purchases the stock cum credit and sells it ex credit, and suppose that the investor does not receive the subsequent dividend. Then, according to the dividend correction rule (9), the investor must report a capital gain equal to:

$$G^\tau = P^e - (P^c + RET_t + D_t) \quad . \tag{11}$$

The step-up amount equals the earnings per share $Y_t = RET_t + D_t$.[2]

Dividend capture. Consider an investor who does not receive the tax credit. Suppose that she purchases the stock cum dividend and sells it ex dividend. Then, according to the dividend

[2]The first year, 1993, the step-up amount is RET_t and, the three subsequent years, 1994-1996, it is $\min(Y_t, 0)$ if $RET_t < 0$, and RET_t if $RET_t \geq 0$.

correction rule (10), the investor must report a capital gain equal to:

$$G^{\tau} = P^{e} - (P^{c} - D_t) \quad . \tag{12}$$

This rule removes the incentive to purchase a tax-free dividend for the purpose of generating a tax-deductible capital loss.[3]

3.3 Legal Risk

The Norwegian tax code contains a general provision against transactions which serve no other business purpose than to avoid taxes. 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 investor files her 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 investors or foreign investors. Therefore, in transactions between a taxed domestic investor and either a tax-exempt domestic investor or a foreign investor, the legal risk is borne by the domestic taxed investor. If the tax avoidance is substantial, the tax-exempt domestic investor may be charged for help with tax fraud.

The provision against tax evasion has been invoked during the time period we study, and we shall investigate its effect on price formation and volume. Following the newspaper coverage of unusual trading around the ex-dividend day of some large stocks in May 1998, the tax authorities audited large banks and brokerage firms. Based upon their investigation of some large transactions between foreign institutional investors 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]The first two years, 1992 and 1993, when the dividend correction rules do not apply, the capital gain is $G^{\tau} = P^{e} - P^{c}$ and the dividend capturer earns a tax-deductible credit in addition to the tax-free capital gain.

4 Costly-Arbitrage Model

4.1 Tax-Credit Capture

A potential buyer meets with a potential seller and bargains over the gains from trade. The buyer can use the step-up amount $Y = RET + D$ to shield taxes at rate τ according to the dividend correction rule (9). The seller is a tax-exempt investor, who cannot use this right. The tax credit is physically attached to ownership of the stock, so a transfer of the tax credit requires that the buyer purchases the stock from the seller and holds it over the distribution of the tax credit. An agreement means that the buyer purchases the stock at the cum-credit price P^c and promises to sell it 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. Neither the buyer nor the seller of the tax credit is exposed to 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 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 capital loss and the transaction costs:

$$(P^e - P^c)(1-\tau) - 2c + \tau Y \geq 0 \quad . \tag{13}$$

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 her transaction costs:

$$P^c - P^e - 2c \geq 0 \quad . \tag{14}$$

We obtain the gains from trade by adding equations (13) and (14):

$$-4c + \tau Y + \tau(P^c - P^e) \geq 0 \quad . \tag{15}$$

The gains from trade are endogenous and depend on how they are divided, because the negotiated capital loss shields taxes in addition to the cost basis adjustment. The two reservation prices (13) and (14) are displayed in Figure 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 investors, while the demand for tax credits is limited only to the extent that there are less expensive ways to shield taxable income. Bertrand competition among potential buyers implies that sellers capture the gains from trade and that (13) holds with strict equality:

$$P^c - P^e = -\frac{2c}{1-\tau} + \left(\frac{\tau}{1-\tau}\right) \times Y \quad . \tag{16}$$

4.2 Dividend Capture

The sequence of arguments is similar. A potential buyer meets with a potential seller and bargains over the gains from trade. The buyer is a domestic investor who must pay taxes at rate τ on trading

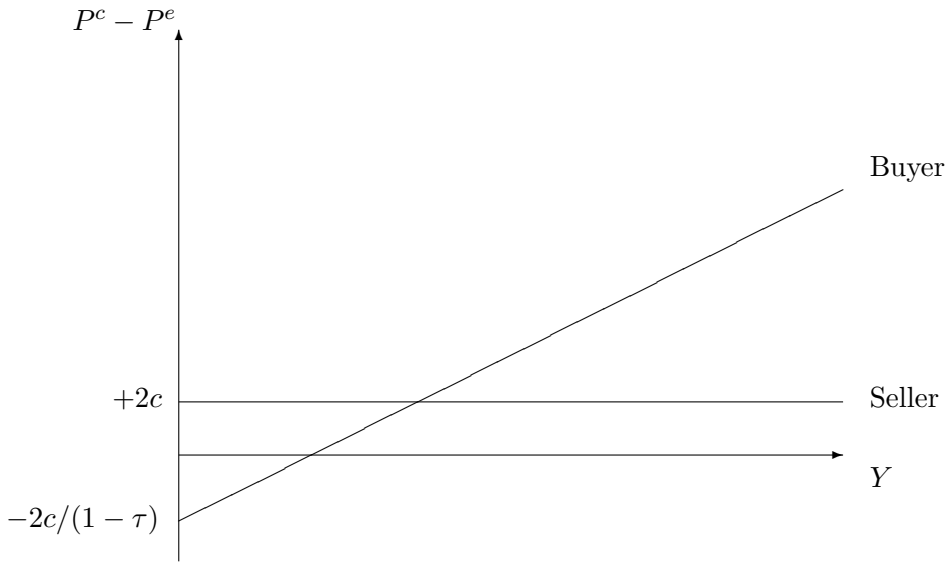

Figure 2: **Reservation Prices for the Tax Credit**: P^c is the negotiated purchase price cum-credit, P^e is the negotiated sell price ex-credit, Y is the step-up amount, τ is the marginal tax rate on capital gains, and $2c$ the round-trip transaction cost.

profits, but is exempt from taxes on dividends. The seller is a foreign investor who is exempt from taxes with the exception of a withholding tax on the dividend at rate τ_w. The dividend is physically attached to the stock, so avoiding the withholding tax requires that the buyer purchases the stock cum dividend and sells it back ex dividend. An agreement means that the buyer purchases the stock at the cum-dividend price P^c and promises to sell it 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, who covers her loss with the cash dividend. We make the analogous Assumptions 1-5 above to ensure that the dividend capture is risk free and fully financed.

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

$$(P^e - P^c) - \tau[P^e - (P^c - D)] - 2c + D \geq 0 \quad . \tag{17}$$

This expression invokes the dividend correction rule (10). The seller is willing to supply the stock

if the capital gain exceeds the after-tax value of the dividend and the transaction costs:

$$P^c - P^e - 2c - (1 - \tau_w)D \geq 0 \quad . \tag{18}$$

The two reservation prices are shown in Figure 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 (17) holds with strict equality:

$$P^c - P^e = -\frac{2c}{1 - \tau} + D \quad . \tag{19}$$

Neither tax rate influences the marginal value of the dividend as a result of the dividend correction rule (10) and competition among buyers, respectively.

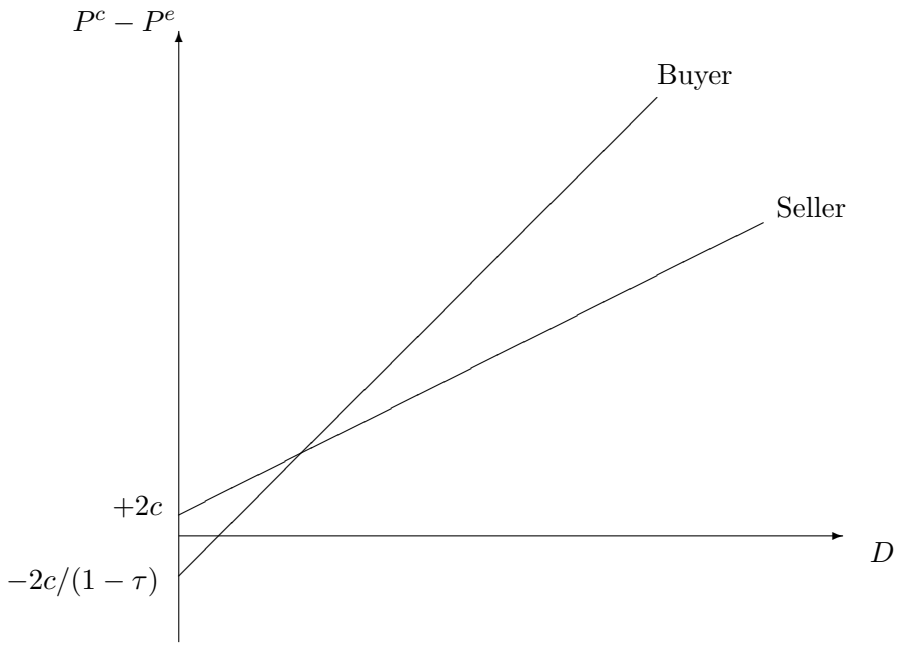

Figure 3: **Reservation Prices for the Dividend**: D denotes the dividend, τ the capital gains tax rate, and $2c$ the round-trip transaction cost.

5 Empirical Analysis

5.1 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 step-up amount per share RET is taken from the official web site of the Norwegian tax authorities. The total data set consists of 1,976 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 1,285 ex-credit days and 652 ex-dividend days.

We also collect ownership data for a subset of firms with positive tax credits and dividends in 1997-1999. We want to see who is trading with whom and whether changes in ownership around the distributions are temporary. Listed Norwegian stocks are kept as book entries by the Securities Register. 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). We purchase daily ownership balances using a window of 30 business days around each distribution. To protect investor 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.

5.2 Testing Methodology

5.2.1 Prices

For the tax credit, we estimate the regression model:

$$\frac{P^c - P^e}{P^c} + E(r) = a + b \cdot \frac{Y}{P^c} + c \cdot PAST + e \quad , \tag{20}$$

where $E(r)$ is the expected return over three to five calendar days between the last business day before the turn of the year and the first business day after, 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. We measure expected return $E(r)$ for common stocks as the realized return on the stock market index from the last business day before the distribution to the first business day after. For preferred stocks, we measure expected return $E(r)$ as the average dividend yield of all preferred stocks times the number of calendar days between the last business day before the distribution and the first business day after. The costly-arbitrage model (16) implies:

$$\begin{array}{rcccl} a & = & -\frac{2c/P^c}{1-\tau} & < & 0 \quad , \\ b & = & \frac{\tau}{1-\tau} & = & 0.389 \quad . \end{array} \tag{21}$$

These predictions are derived under the assumption that the discount rate is zero. Using a positive discount rate, the predicted slope coefficient decreases below 0.389. For example, if the continuously-compounded, annual discount rate is 10%, we expect that $b = 0.346$.

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 $PAST$ in the regression. Since we want to make inference from the magnitude of the intercept, we subtract the sample average. We do not control for firm size, because most Norwegian firms are essentially small, and we do not control for ownership by individuals or institutions, because we do not have data except in 1997-1999.

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

$$\frac{P^c - P^e}{P^c} + E(r) = a + b \cdot \frac{D}{P^c} + e \quad . \tag{22}$$

The costly-arbitrage model (19) implies:

$$\begin{array}{rcl} a & = & -\frac{2c/P^c}{1-\tau} \quad < \quad 0 \quad , \\ b & = & 1 \quad . \end{array} \tag{23}$$

We estimate both regression models (20) and (22) with ordinary least squares. To asses the impact of a possible change in legal risk, we also interact the yield variable with one dummy variable for the time period before the tax audit in May 1998 and another for the time period after the tax audit. The panel is unbalanced and we shall ignore possible fixed-firm effects. Since we adjust the dependent variable for stock market movements, which is equal across all firms at the turn of the year, we make no further adjustments for fixed-time effects.

5.2.2 Trading Volume

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

$$\ln(TO) = a + b \cdot \frac{Y}{P^c} + c \cdot PAST + e \quad , \tag{24}$$

and

$$\ln(TO) = a + b \cdot \frac{D}{P^c} + e \quad , \tag{25}$$

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 the average daily return from the past year $PAST$. The previous literature suggests that $c < 0$ (see Dyl (1977)). Our regression models deviate from the literature in two important

ways. Firstly, we do not subtract expected turnover from observed turnover. Secondly, we do not include variables which control for transaction costs and risk.[4] The reason is that trading volume 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, or proxy variables for risk and transaction costs, outside the event period.

5.2.3 Changes in Ownership

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

$$P\Delta N_s = \beta D N_s \quad , \tag{26}$$

where Δ denotes change and $\beta \geq 0$ is a proportionality constant. We divide both sides of the equation with firm size:

$$\Delta\theta_s = \beta\left(\frac{D}{P} \times \theta_s\right) \quad . \tag{27}$$

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:

$$\Delta\theta_i = \alpha_i^j + \beta_i^j\left(\frac{D}{P} \times \theta_s\right) + \varepsilon_i^j \quad . \tag{28}$$

Subindex $i = b, s$ denotes trading volume by buyers and sellers, and superindex $j = c, e$ trading volume cum dividend and ex dividend. We shall estimate equation (28) for each combination of buyers and sellers, cum and ex ownership data. Dividend capture predicts:

$$\begin{aligned} \beta_s^c < 0 \quad \text{and} \quad \beta_s^e > 0 \quad . \\ \beta_b^c > 0 \quad \text{and} \quad \beta_b^e < 0 \quad . \end{aligned} \tag{29}$$

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

Since buyers and sellers interact, we must also have:

$$\begin{aligned} \beta_s^c + \beta_b^c &= 0 \quad . \\ \beta_s^e + \beta_b^e &= 0 \quad . \end{aligned} \tag{30}$$

Finally, if the change in ownership is temporary and ownership swifts back to its original level after the distribution, we must also have:

$$\begin{aligned} \beta_s^c + \beta_s^e &= 0 \quad . \\ \beta_b^c + \beta_b^e &= 0 \quad . \end{aligned} \tag{31}$$

A corresponding set of regression equations (28) and restrictions (30)-(31) can be derived for the tax credit. The tax-exempt ownership fraction replaces the foreign ownership fraction, and the step-up yield Y/P replaces the dividend yield D/P.

5.3 Descriptive Statistics

Table 2 reports summary statistics for the price and volume variables. We can see in Panel A that the average market-adjusted price drop over the distribution of the tax credit is negative, which means that expected returns over the turn of the year are positive despite the distribution of the tax credit. Hence, on average, the turn-of-the-year effect dominates the tax-credit effect. We can also see 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. The basis adjustment is zero when the firm can shelter income from corporate taxes with loss deductions, depreciations (notably in the offshore sector), or when income is tax free (shipping). The step-up yield can be negative when a parent receives a large intra-firm dividend from a subsidiary. The extreme negative step-up yield in the amount of -62.4% is related to default and an artefact of dividing lagged book income with a low stock price. The extreme positive step-up yield is 52.4%.

We can see in Panel B that the average market-adjusted price drop is 3.9%, which is less than the average dividend yield 4.3%. Hence, consistent with the extant ex-dividend day literature, the

Table 2: **Price and Volume Variables**

	Mean	**Std**	**Min**	**Max**	**#Obs**
A. Tax credit					
Price drop	-0.013	0.059	-0.502	0.240	1,285
Step-up yield	0.028	0.071	-0.624	0.524	1,285
Turnover	0.055	0.090	0.000	2.028	1,285
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 price minus the ex-distribution price divided by the cum-distribution price. For common stocks we add the stock market return over the holding period (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 shares outstanding.

price drop divided by the dividend is less than one. The extreme dividend yield is 76.5%. The average turnover during the event period is approximately 5% and the maximum above 200%.

Table 3 reports the ownership structure of Norwegian stocks in the beginning of December 1999. Taxed investors (A) own 31% and tax-exempt investors (B) 38.8%. Foreign investors (C) and a few domestic investors with unknown type own the remaining 30.2%. The largest sectors are non-financial corporations, the public sector (primarily the Government pension fund), and foreign investors. Mutual funds and private pension funds are relatively small. Individuals own 8.9%.

5.4 Regression Results

The results of estimating the price regressions (20) and (22) are reported in Table 4. Starting with the tax-credit regressions, we can 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 audit but nevertheless smaller than predicted by the costly-arbitrage model (21). The coefficient

Table 3: **Ownership Structure**

A. Taxed investors		**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.

of the past return variable is consistent with the literature which shows that stocks with poor past performance have higher returns over the turn of the year. Turning to the dividend regressions, we can see that the intercepts are negative and the slope coefficients close to one as predicted by the costly-arbitrage model (23). The slope coefficient is approximately equal to one both before and after the tax audit.

Table 5 displays the results from the volume regressions (24) and (25). 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 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 (negative past return) than winner stocks (positive past return).

The results of estimating the ownership regressions (28) can be found in Table 6. Ownership changes at the aggregate sector level are noisy and we are able to detect statistically significant patterns only around the ex-dividend day. Therefore, we do not report any results relating to the distribution of the tax credit. Furthermore, we report only the results for three sectors: Foreign investors (sellers), non-financial corporations (buyers), and banks (buyers). The results for all other

Table 4: **Price Regressions**

	Tax credit		**Dividend**	
Intercept	-0.0173 (0.0018)	-0.0175 (0.0018)	-0.0039 (0.0021)	-0.0045 (0.0023)
Yield	0.137 (0.019)		0.991 (0.030)	
Pre Audit×yield		0.201 (0.021)		1.039 (0.046)
Post Audit×yield		0.110 (0.023)		0.979 (0.029)
Past return	1.484 (0.625)	1.469 (0.623)		
t-test		3.3		1.3
R^2	0.036	0.038	0.635	0.635
#Obs	1,285	1,285	652	652

Ordinary least squares regression 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.

sectors are statistically insignificant.

Panel A reports the results of ordinary least squares estimation. 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 slope coefficients pre audit are statistically different from zero, and that the slope coefficients post audit are not significantly different from zero. For foreign investors, the slope coefficient pre audit is negative cum dividend and positive ex dividend and for corporations and banks the signs are reversed. These patterns suggest that foreign investors sell cum dividend and buy back ex dividend and that corporations and banks buy cum dividend and sell 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 (31). Statistical tests cannot reject the hypothesis that the slope coefficients cum and ex dividend sum to zero (not reported). The statistical insignificance of all slope coefficients post audit suggests that traders do not engage in tax trading after the tax audit. The t-statistics in the rightmost column show that

Table 5: **Volume Regressions**

	Tax credit		**Dividend**	
Intercept	-3.489 (0.037)	-3.496 (0.037)	-3.886 (0.059)	-3.968 (0.071)
Yield	-0.663 (0.508)		0.084 (0.744)	
Pre Audit×yield		1.563 (0.723)		6.648 (1.957)
Post Audit×yield		-1.590 (0.570)		-1.489 (1.240)
Past return	-15.510 (8.965)	-16.043 (8.963)		
t-test		3.2		4.2
R^2	0.003	0.010	-0.001	0.036
#Obs	1,285	1,285	652	652

Ordinary least squares regression of the log of turnover during the vent period -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.

the differences between the slope coefficients pre audit and post audit 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 (30) imposed on the slope coefficients, i.e., the slope coefficients of foreign investors, corporations, and banks sum to zero for each combination of cum and ex, pre audit and post audit (four restrictions). The slope coefficients suggest that foreign investors (-0.43) sell to domestic investors 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 30.1% and the slope coefficient of foreign investors pre audit -0.43 to conclude that 0.55% of the outstanding shares are transferred to Norwegian banks (0.22%) and corporations (0.33%) to avoid the withholding tax on dividends.

In comparison with the previous literature on ex-dividend day trading, the point estimate 0.55% is quite large. For example, Michaely and Vila (1996)) show that abnormal trading volume around the ex-dividend day averages 0.16% of the shares. Dividing this number by four (buy and sell,

Table 6: **Ownership Changes Around the Ex-Dividend Day**

		Intercept	**Pre audit**	**Post audit**	**R^2**	**t-test**
A. Ordinary						
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						
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 investors, corporations, and banks sum to zero cum and ex, pre audit and post audit (four restrictions).

cum and ex), we conclude that ownership of 0.04% of the shares is temporarily shifted around the ex-dividend day in their sample. However, in comparison with the foreign ownership fraction 30.1%, the point estimate 0.55% is quite small and suggests that static tax clientele models such as Brennan (1970) and Allen, Bernardo, and Welch (2000) may have predictive power despite the trading around the ex-dividend day.

5.5 Errors-in-Variable Bias

The evidence 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 (20) assumes that investors observe the step-up yield without error while, in fact, investors must trade on inaccurate earnings-per-share forecasts. Brokers supply earnings-per-share forecasts to their customers, and I/B/E/S forecasts are available for large Norwegian stocks. I/B/E/S coverage is highly incomplete, so earnings-per-share forecasts are not a feasible instrumental variable for our study. Instead, we address the estimation problem with simulations.

Table 7: **Simulation Results**

	Intercept	**Slope**	$\mathbf{R}^2$
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 1,285 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.

We start with the sample of observed step-up yields X. Next, we generate the dependent variable Y from the estimated intercept in Table 4, the theoretical slope parameter, and a normally distributed error term:

$$Y = -0.0172 + 0.389X + e \quad , \tag{32}$$

The scale of the error term is chosen such that the standard deviation of Y approximates the observed standard deviation. We estimate the regression parameters using the generated data and report the average regression parameters across 500 simulations. Finally, we repeat the regressions after adding a normally distributed error term u with mean zero and standard deviation σ_u to the independent variable, $X + u$. The simulation results are reported in Table 7. Panel A reports the true parameters and Panel B the average estimated parameters for different magnitudes of the error term. The magnitude of the error term can be compared to the standard deviations of Y and X which are 0.057 and 0.071, respectively. We can see that the average estimated parameters are close to the true parameters when there is no error. We can also see that there is an errors-in-variable bias which increases with the standard deviation of the error term. The table demonstrates that very large errors are required to generate a slope coefficient of the magnitude we observe in Table 4. Hence, we conclude that errors-in-variable bias does not account for the rejection of the costly-arbitrage model.

5.6 Event Study of Preferred Stocks

Preferred stocks are debt-like securities with a claim on the annual dividend, but with no claim on the retained earnings. Nevertheless, as a result of a mistake in the tax code, preferred stockholders earn an imputation-tax credit for retained earnings. In September 2000, the Government corrects the mistake in the tax code and eliminates the tax credit to preferred stockholders. Figure 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 dates. This is an estimate of the market value of future imputation-tax credits attached to preferred stocks. The estimate is large and reflects the fact that the average realized step-up yield for preferred stocks in 1993-2000 is

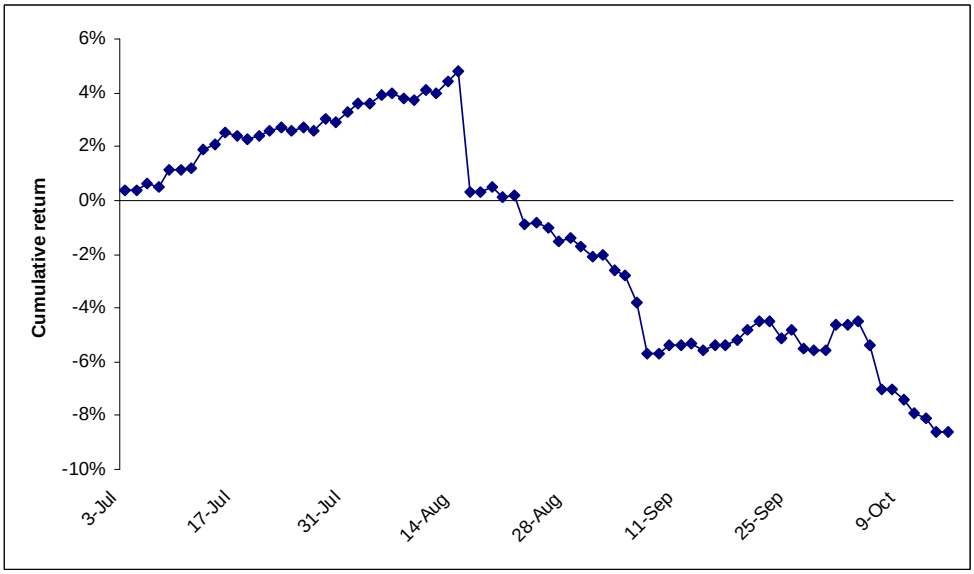

Figure 4: **Market Reaction to the Elimination of Tax Credits to Preferred Stocks.** Equally-weighted average, cumulative return of 21 preferred stocks around the announcement of a change in the tax code that eliminates future imputation-tax credits for preferred stocks.

20%.[5]

6 Conclusions

In this paper, we have shown that the costly-arbitrage model of price formation is consistent with observed return patterns around the ex-dividend day in Norway. We have also shown that the costly-arbitrage model is inconsistent with observed return patterns around the distribution of the tax credit. In particular, the estimation results suggest that arbitrageurs are unwilling to compete away all profits from trading the tax credit. We have also found that trading volume increases with the tax credit, but trading around the ex-credit day is much less pronounced than trading around the ex-dividend day.

What explains the rejection of the costly-arbitrage model in one case but not in the other? We have examined how the increase in legal risk after the tax audit influences trading behavior. While

[5]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.

trading volume is severely reduced, we do not see much effect on price formation, so legal risk does not seem to account for the rejection of the costly-arbitrage model. We have also examined the role of estimation risk which may explain the price formation around the distribution of the tax credit, but this explanation leaves us with the puzzle as to why arbitrageurs demand a risk premium for diversifiable estimation risk. Furthermore, estimation risk does not apply to any of the other tax-credit cases in Table 1, so estimation risk cannot be the answer to the general puzzle as to why the pre-tax value of imputation-tax credits are not fully reflected in market prices. We leave this question to future research.

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