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Corporate taxes, investment and the self-financing rate

The effect of location decisions and exports

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TALL SOM FORTELLER

DISCUSSION PAPERS

955

Discussion Papers No. 955, May 2021
Statistics Norway, Research Department

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Abstract:
In this paper, we study how lower corporate tax rates impact investment by including two novel channels into a DSGE model used for fiscal policy analysis in Norway. We capture both how foreign firms relocate and invest in the country when corporate taxes are reduced and how the inflow of FDI increase exports which spills over to domestic firms who then increase their investment further. We find that a one percentage point reduction in the corporate tax rate increases investment by 0.6%, most of which can be attributed to the FDI-export link. The corporate tax cut becomes self-financed when the FDI-export link is included, but only if other countries do not follow suit and also lower their corporate tax rates. When using the model to analyze the tax reform in Norway from 2014 to 2019, we find overall positive effects on investment and employment.

Keywords: Corporate profit tax, Foreign direct investment, Exports, Imports, User cost of capital, Depreciation, Tax reform

JEL classification: E62, H21, H25, H32

Acknowledgements: The views expressed in this paper are those of the authors and do not necessarily represent those of Statistics Norway, the Norwegian Ministry of Finance, Deutsche Bundesbank or the Eurosystem. We are grateful to Nina Bjerkedal, Geir Bjertnæs, Brita Bye, Yngvar Dyvi, Håkon Frede Foss, Frode Olav Finsås, Inga Heiland, Erling Holmøy, Birol Kanik, Thomas Klev, Terje Skjerpen, Thor Olav Thoresen, Håkon Tretvoll, and seminar participants at the Norwegian Ministry of Finance for helpful comments and discussions. The responsibility for any errors lies entirely with us.

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ISSN 1892-753X (electronic)

Sammendrag

I denne artikkelen analyseres effekten på investeringer og andre makroøkonomiske hovedstørrelser som følge av lavere selskapsbeskatning i Norge. Vi bruker en utvidet versjon av den makroøkonomiske modellen NORA i analysen. Den utvidete modellen fanger opp tre kanaler som lavere selskapsskatt virker gjennom: for det første reduseres brukerprisen på kapital, noe som gjør investeringer mer lønnsomt. For det andre blir det mer lønnsomt å drive økonomisk aktivitet i Norge, slik at flere utenlandske selskaper flytter virksomheter hit. For det tredje bidrar reallokering av virksomheter til Norge også til økt eksport og økt aktivitet i andre norske virksomheter. Artikkelen bidrar til faglitteraturen ved å inkorporere de to siste kanalene i en helhetlig modellanalyse. Det er kun ved å inkludere alle de tre kanalene at modellen gjenskaper empirisk etablerte sammenhenger fra endret selskapsskatt til endrete investeringer på den ekstensive marginen og eksportøkninger.

Vi finner at en reduksjon i selskapsskatten på ett prosentpoeng i Norge øker investeringer i Fastlands-Norge med 0,6 prosent. Det meste av denne økningen kan tilskrives økningen i eksportetterspørsel som følge av økte direkteinvesteringer fra utlandet. Når vi derimot ser på tilfellet der selskapskatten reduseres både i Norge og i utlandet øker investeringene i Fastlands-Norge med kun 0,1 prosent, ettersom utenlandske virksomheter da ikke får et insentiv til å endre lokalisering.

Vi analyserer også selvfinanseringsgraden ved en endring i selskapsskatten. Selvfinansieringsgraden viser hvor mye av den umiddelbare skatteletten som hentes inn på lang sikt på grunn av økt økonomisk aktivitet og økte skattebaser. Hvis vi skrur av reallokerings-effektene finner vi en selfinansieringsgrad på 57 prosent, som er noe lavere enn hva andre studier viser for en del europeiske land. Når vi derimot inkluderer effektene av at utenlandske virksomheter flytter til Norge og påvirkningen dette har på innenlansk eksport, øker selvfinansieringsgraden til 124 prosent. Modellberegningene viser dermed et langsiktig proveny på 24 kroner når det gis 100 kroner i skattelette som følge av lavere selskapskatt.

Vi bruker også den utvidete NORA modellen til å analysere den norske skattereformen fra 2014 til 2019, hvor blant annet selskapsskatten ble redusert fra 28 til 22 prosent. Ved å anta uendrete skatter i utlandet viser modellberegningene at den norske skattereformen bidrar til å løfte investeringer med rundt 3,5 prosent og BNP Fastlands-Norge med 1,1 prosent på lang sikt. Selvfinansieringsgraden av reformen estimeres til rundt 135 prosent. Men, den norske skattereformen må sees i sammenheng med reduserte selskapskatter internasjonalt. Ved å skru av effektene som følger av reallokering og overskuddsflytting blir selfinansieringsgraden av den norske skattereformen 73 prosent og investeringene øker med 0,8 prosent. Vi har ikke analysert velferdseffekter mer generelt eller hvordan skattereformen har påvirket graden av ulikhet i samfunnet.

1 Introduction

The passthrough from corporate taxes to investment has been a core area of analysis in economics for decades. A channel through which taxes affect investment behavior is their impact on the user cost of capital, and thus the intensive margin of investment. During the last two decades, there has been, however, increased academic interest in analyzing how corporate taxes impact investment at the extensive margin through discrete location choices. This topic has also been at the forefront of the political agenda, recently exemplified by the call, from US Secretary of the Treasury Janet L. Yellen, for a minimum global corporate income tax to prevent U.S. companies to relocate overseas (Yellen, 2021). The call can be seen as a reaction to the corporate tax reforms undertaken by many countries over the last decades to inter alia make investment more attractive to internationally mobile firms. As a result the average corporate tax rate in the OECD was reduced from 32.3 % in 2000 to 23.5 % in 2020, see Figure 1.

In this paper, we identify how changes in the corporate tax rate impacts investments by extending a DSGE model used for fiscal policy analysis in Norway (Aursland et al., 2020) to include relocation effects. Our extended model captures three distinct channels for how a lowering of the corporate income tax increases investment. First, it lowers the user cost of capital, so domestic firms increase investment. Second, it increases the investments through the extensive margin,

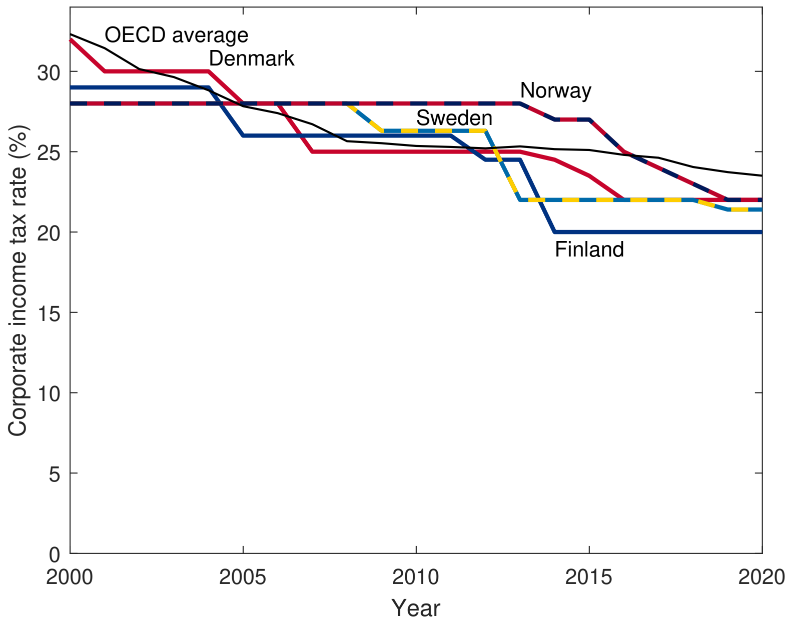

Figure 1: Corporate income tax rate in Nordic countries and OECD average. The graph shows combined statutory corporate tax rates for period 2000 to 2020 obtained from OECD Tax Database.

as some foreign firms decide to relocate and invest in the country. In doing so we capture that in contrast to the user cost channel, where the marginal return on investments is the relevant decision-making margin, it is the average after-tax return on investments across different locations that determines where firms decide to operate (Devereux and Griffith, 2003). Third, the inflow of foreign direct investment (FDI) increase exports which spills over to domestic firms who then increase their investment further. We refer to this latter channel as the FDI-export link.

We add to the literature by analysing both locations shifts and FDI-export link. To identify locations shifts, we extend the model with a micro-founded block inspired by the model in Becker and Fuest (2011) of optimal tax policy when firms are internationally mobile. To identify the FDI-export link, we extend the model with a block inspired by the empirical specification in O'Sullivan (1993) and the comprehensive evidence that the attraction of FDI has positive spillover effects on export demand in the host country, see Popovici (2018) and Kastratović (2020).

It is only when we incorporate both the FDI-export link and location shifts that we can account for the empirically observed response of exports and extensive-margin investment to corporate tax cuts, see e.g. Mooij and Ederveen (2008). We find that a one percentage point reduction in the corporate tax rate in Norway increases investment by 0.6 %, most of which can be attributed to the increase in export demand following the increase in foreign direct investment. In the absence of the FDI-export link, fewer firms deem it profitable to relocate so the extensive margin investments increase significantly less. Furthermore, the absence of the additional foreign export demand weakens investment at the intensive margin leaving a total investment response of 0.1 %. When we alternatively assume that the tax rates in other countries decrease symmetrically so there is no relocation, total investments increase by 0.1 %. Earlier models most closely related to our study are Radulescu and Stimmelmayr (2010), Bettendorf et al. (2010), Coenen et al. (2012), Bjertnæs (2018), Hanappi (2018) and Alvarez-Martínez et al. (2019). All these models capture how a reduction in the corporate tax rate impacts the intensive margin through a reduction in the required return on investment. Some of these models also capture the depreciation allowance channel. In addition, Bettendorf et al. (2010), Bjertnæs (2018) and Alvarez-Martínez et al. (2019) study the effect of profit shifting, the debt equity choice of firms and different options for financing domestic investments for international investors. However, none of these studies capture how international firms change location when average tax rates are reduced, nor do they capture the FDI-export link.

Our article also relates to the literature studying the self-financing rate of corporate taxes. Previous studies have found a self-financing degree ranging from 70 % to 90 % for some European countries and the USA, see Trabandt and Uhlig (2011) and Strulik and Trimborn (2012). In line with this literature, we find that when firm relocation in our model are switched off, the self-financing rate is 57 %. However, we find a self-financing degree of 124 % when including these channels, meaning that government can save NOK 24 for every NOK 100, given as tax relief. The largest self-financing contributions come from increases in various labor and consumption tax bases.

Finally, we use the model to analyze the tax reform in Norway from 2014 to 2019, where, inter alia, the corporate tax rate was gradually reduced from 28 % in 2013 to 22 % in 2019. The Norwegian tax reform can be seen as a response to the international development of corporate tax harmonization, see e.g. Pirvu (2012) and Keen and Konrad (2013). Moreover, Regis et al. (2015) found that in Europe, tax convergence has taken the form of club convergence across Central-Western European countries, including the Nordic countries, c.f. Figure 1.

We find that the Norwegian tax reform from 2014 to 2019 increases investment by about 3.5 % and mainland GDP by about 1.1 % in the long-run, when assuming unchanged foreign tax rates. In the labor market, the reform contributes to a 0.2 pp increase in the labor force participation rate and a 0.2 % increase in the number employed. The self-financing rate is estimated to be around 135 % when firm relocation and profit shifting are included. However, since other countries have made corresponding reductions in the corporate income tax, these estimates alone may paint an overly rosy picture. The self-financing rate of the reform when firm relocation and profit shifting are excluded, proxying a situation in which other countries lower tax rates symmetrically, is 73 %.

The rest of the paper proceeds as follows. In Section 2, we present our fiscal policy model, with a focus on how FDI impacts exports and the intensive and extensive margins of firm behavior. Section 3 provides information about the data used for aggregate real and tax depreciation rates and the calibration of the parameters governing the location decision of firms. In Section 4, the effects of a corporate tax cut are analyzed, and the relative importance of the user cost channel, location decisions and the FDI-export link is decomposed. Section 5 applies the model to Norway's tax reform of 2014 to 2019. Section 6 provides a conclusion.

2 The model

In this section, we first describe the general characteristics of the original NORA model as published in Aursland et al. (2020). The original NORA model serves as a basis for the novel extensions, which are the main subject of this paper and which are laid out in detail in the subsequent parts of this section.

2.1 Overview of the fiscal policy model NORA

NORA belongs to the class of DSGE models of small open economies and shares many elements with prominent examples such as Monacelli (2005), Adolfson et al. (2007) and Justiniano and Preston (2010). The model economy is assumed to have strong trade and financial linkages with the rest of the world but is sufficiently small not to affect the world economy itself. Foreign variables are transmitted to the domestic economy through movements in the real exchange rate, the yield on foreign bonds and the demand for exports.[1]

There are two types of households in the economy. First, an infinitely-lived utility-maximizing (Ricardian) household earns labor income from employment in the private and public sectors as well as capital income from interest and stocks. The household chooses how much to consume and how much to save in the form of bank deposits and stocks. Second, the liquidity-constrained household does not smooth consumption across periods and instead consumes its entire income net of taxes each period.

The production side of the economy consists primarily of monopolistically-competitive firms producing intermediate goods.[2] Firms use labor and capital to produce an intermediate good that is bundled with imported goods to make different types of final goods, including an export good. The firms face a choice between paying out dividends to stock holders or investing in fixed capital used in production.[3] Investment is financed through both retained profits (equity) and borrowing from banks (debt).[4] Going beyond the original NORA model, we include a location decision by firms based, among other things, on the rate of corporate profit taxes in possible firm locations. This will be expanded upon in the next section.

A distinguishing feature of the Scandinavian countries is the role of wage formation; see e.g. Barth et al. (2014). Consistent with the institutional framework for wage bargaining in Norway (the so-called "frontfag" model), we assume that wage negotiations in the exposed sector of the economy set the norm for wage growth in the rest of the economy.[5] Specifically, we assume that wages are set by Nash bargaining between a labor union aiming for a high level of wages and an

[1] Consistent with most analyses of the Norwegian economy, NORA focuses on developments in the mainland economy, i.e. excluding the offshore oil sector.

[2] In NORA, firms are grouped into manufacturing and service sectors, where manufacturing sector firms are more exposed to competition from abroad, both through imported goods and through their reliance on exports. However, for the purpose of this paper, this distinction is irrelevant as we only investigate the aggregate investment response in the economy.

[3] DSGE models often assume, for simplicity, that households invest in fixed capital that they subsequently rent out to firms. Our more realistic depiction of the investment process allows us to describe the effect of tax changes on investment more accurately. Note, also, that housing investment in NORA is exogenous and not affected by corporate tax rates.

[4] We do not take account of the issuance of new equity, as underwriting commissions and other fees tend to make issuance a more costly alternative than retained earnings or debt (Alstadsæter and Fjærli, 2009).

[5] An important purpose of this setup, which builds on the so-called main-course theory developed by Aukrust (1977), is to preserve the competitiveness of the exposed sector and to ensure a high level of employment.

employer organization aiming for high profits in the exposed sector. High unemployment, ceteris paribus, is assumed to weaken the bargaining position of unions and lead to lower wage demands. The result is a negative relationship between the real wage level and the unemployment rate, often referred to as the "wage curve"; see Blanchflower and Oswald (2005). Labor force participation is modeled in reduced form and responds to the after-tax wage and the unemployment rate according to Dagsvik et al. (2013).

NORA includes a relatively disaggregated description of government spending and taxation. In particular, households pay a flat tax on their total (ordinary) income, a surtax on labor income and transfers as well as social security contributions. NORA holds also a detailed description of the Norwegian system of shareholder income taxation, which represents an Allowance of Shareholder Tax (ASE) system. This includes, inter alia, a rate-of-return allowance on stocks. The deduction has the effect that the return up to the rate-of-return allowance is exempt from taxation while only the remaining equity premium on stocks is taxed at the household level. This leads to a neutrality of the household's dividend tax with respect to investment decision.

Firms pay taxes on their profits net of deductions and social security contributions for their workers. There is symmetry between the taxation of corporate income and household ordinary income in the Norwegian tax code. Although the tax rates for corporate and household income are equal in the baseline calibration, they are modelled as two distinct tax rates in NORA, which allows us to isolate the impact of changing the corporate tax rate only.

The government also receives an exogenous stream of funding from the offshore sovereign wealth fund, the Government Pension Fund Global (GPFG). In 2020, the value of GPFG was around 3.5 times the value of GDP Mainland Norway. According to the fiscal policy rule, transfers from GPFG to the central government budget shall, over time, follow the expected real return on the fund, estimated to be around 3 per cent annually. A significant portion of government spending in Norway is thus financed by withdrawals from the fund. Taxes and withdrawals from the GPFG are used to finance government expenditures, which consist of unemployment benefits, purchases of goods and services from the private sector, government employment, and public investment. The central bank is assumed to follow a rule mimicking optimal monetary policy, subject to a zero lower bound on the nominal interest rate.

The effect of a corporate tax cut in the extended version of NORA operates through three main transmission channels. First, a tax cut increases the incentive to relocate through the extensive margin. Second, the resulting inflow of foreign investment boosts exports through the FDI-export link. Third, it lowers the user cost of capital, so domestic firms increase investment. In the following, we outline these three channels in that order in detail.

2.2 The location decision of firms

There is a continuum of firms in our model, of which a share decides to locate in Norway. The location decision of an individual firm is made by comparing its potential after-tax value in and outside Norway, a setup inspired by Becker and Fuest (2011).

The firm's value if it decides to produce abroad (i.e. outside of Norway) depends on the taxation of corporate profits abroad and on a fixed firm-specific mobility cost that firms need to pay if producing there.[6] These fixed costs are permanent to the firm and drawn randomly from a uniform distribution. The value of the firm when locating abroad would principally also depend on foreign cost of capital and wage costs. However, we keep those other determinants of the value of foreign firms fixed in our analysis to focus solely on the effects of changes in Norways tax system on relocation choices. In fact, for the sake of our analysis the value of a specific firm when producing abroad is fixed since we keep all of its determinants constant.

However, the value of a firm when producing domestically, which will be modeled in much greater detail and presented in section 2.4, changes for each firm when Norway changes its corporate profit tax rate. By comparing a firm's value abroad with its value in Norway we determine where a firm decides to locate. We also obtain the critical value of fixed mobility costs. Firms with that level of fixed costs are exactly indifferent with respect to their location choice. Firms with fixed costs below that threshold decide to locate abroad while the remaining firms find it optimal to produce in Norway.

Specifically, we assume the existence of a continuum of firms $i \in [0, 2]$ capturing the entire universe of firms that could potentially locate in Norway. A share n_t^D of these firms produces in Norway at time t, the remaining share $n_t^F = 2 - n_t^D$ produces abroad. In the initial steady state we normalize n^D to 1 such that initially half of all firms that are able to locate in Norway do actually produce there.[7] We assume that firms $i \in [0, 1]$ are always owned by Norwegians, with the rest of firms under foreign ownership, regardless of whether these firms move abroad or to Norway.[8] The firms decide on whether to manufacture in Norway or abroad. If and only if they decide to manufacture abroad, they face fixed costs $c(i)$, which are specific to the firm. We assume that firms draw their (permanent) fixed mobility cost from a uniform distribution $[(1 - b)a, (1 + b)a]$, where a is the center of the uniform distribution and b the (relative) spread.

[6] Note that these fixed mobility costs could be negative, implying a ceteris paribus benefit of producing abroad.

[7] Note that this assumption is motivated by numerical convenience rather than empirical fact, but involves no loss of generality. Any initial steady-state allocation of firm location could be calibrated without changing our results. The key calibration moment, as will be shown later, is the range of fixed mobility costs across firms.

[8] This assumption is a slight relaxation of the assumption in Becker and Fuest (2011), where all firms are owned by domestic households. They show, however, that a symmetric setup with locals and foreigners holding shares in both domestic and foreign firms do not change the result in any important way.

Value of a firm located abroad To keep the model as parsimonious as possible we assume two key simplifications for the foreign-located firm model: Foreign production does not employ any labor and capital is entirely debt financed. As will be clear below, these simplifications have no bearing for our results.

The production is given by $Y_t^F(i) = A^F(K_t^F(i))^{\alpha_F}$, where A^F is a parameter capturing productivity, K^F is the capital stock and α_F the capital elasticity. To produce abroad a firm needs to rent the capital stock at the foreign real market interest rate, which is given by r_t^F. Dividends (after-tax profits) in the foreign location are then given by

$$DIV_t^F(i) = [Y_t^F(i) - c(i) - r_t^F K_t^F](1 - \tau_t^F), \tag{1}$$

where τ_t^F the foreign corporate tax rate. The optimal capital stock for firms deciding to produce abroad follows from profit maximization, taking into account the capital accumulation constraint, and is given by

$$\alpha A^F (K_t^F)^{\alpha-1} = \frac{r_t^F}{1-\tau_t^F} + \delta^F, \tag{2}$$

where δ^F is the depreciation rate of capital abroad. Hence, firms deciding to produce abroad will increase their capital stock up the point when the marginal product of capital (left-hand side of the equation) equals the marginal cost of capital abroad (right-hand side), given by the foreign interest rate, tax rate and depreciation rate.[9]

To derive the net present value of dividends, and thus the value of the firm, we use the foreign interest rate to discount the dividend stream:

$$V_t^F = \sum_{i=1}^{\infty} \left(\prod_{j=1}^{i} \frac{1}{1+r_{t+j}^F} \right) RER_{t+i} DIV_{t+i}^F. \tag{3}$$

where RER_t is the real exchange rate.[10] Hence, we measure the value of the firm in Norwegian currency. From the definition of profits it follows that the value of a foreign-located firm $V_t^F(i)$ falls with its idiosyncratic mobility cost $c(i)$. However, since fixed costs are constant for each firm, as is the foreign interest and tax rate, the value of the firm when locating abroad is fixed. This would also be the case if we modeled labor costs (assuming a constant wage) and an equity financing decision.

[9] The corporate tax rate abroad, τ_t^F, is calibrated such that it implicitly captures capital depreciation allowances; see the calibration section. Thus, we do not explicitly model capital depreciation allowances, as opposed to the case of domestic firms; see section 2.4.

[10] We assume that the foreign real interest rate is fixed. However, the results remain practically unchanged even if we impose the movements of the Norwegian real interest rate on the interest rate abroad.

The threshold fixed mobility cost We can identify the level of mobility costs at which firms are exactly indifferent to location by setting

$$V_t = V_t^F(\widetilde{c}_t), \tag{4}$$

where V_t is the value of the firm if it decides to produce in Norway. This will be introduced later on. In the case of equality, the value of the firm when locating abroad equals the value of the firm when locating in Norway. If the interval $[(1-b)a, (1+b)a]$ is sufficiently large, then for any value of V_t, there will be a mobility cost of indifference $\widetilde{c}_t$ which solves equation 4.[11]

Solving for $\widetilde{c}_t$ pins down the number of firms locating abroad (n_t^F). This is because firms are uniformly distributed across the range of possible fixed mobility costs $[(1-b)a, (1+b)a]$ and the share of firms below and above the threshold can be easily calculated. Specifically, the number of firms finding it optimal to locate abroad is given by $n^F = \frac{\widetilde{c}_t-(1-b)a}{ba}$.[12] It is important to note that the spread parameter b determines how sensitive the number of firms abroad is to changes in $\widetilde{c}_t$. The larger b is, the smaller will be the number of firms deciding to relocate for a given change in the threshold value (e.g. caused by a corporate tax cut), simply because the range of possible fixed mobility costs becomes wider. We will exploit this property in calibrating the parameter b; see section 3.

Since moving is itself a process that takes place with a considerable time lag in reality, we consider a slowdown of the moving decisions expressed by

$$n_t^F = \rho^n \frac{\widetilde{c}_t - (1-b)a}{ba} + (1-\rho^n) n_{t-1}^F, \tag{5}$$

where ρ^n is the speed at which firms actually make the move, given that they find it optimal to move. For $\rho^n = 1$, all firms that find it optimal to move will do so instantaneously. For $\rho^n < 1$, only a share of firms will move in time t; the others will follow in later periods. The choice of this parameter allows us to square the model's predictions of the evolution of foreign investment following a corporate tax cut with empirical evidence discussed in the calibration section 3.

After a firm moves to Norway, it faces the same optimization problem as the pre-existing Norwegian firms discussed in section 2.4. Part of the capital stock that is deemed optimal, given the decision to produce in Norway, is built in Norway and forms part of the demand for domestic investment goods in the relocation period, while the remaining part is imported. For the sake of simplicity, we assume there are no costs associated with this capital transformation.

[11] We set the center of the interval, a, to the steady-state value of the threshold mobility cost, i.e. $a = \widetilde{c}_{ss}$, thereby ensuring that in steady state the threshold mobility cost exactly halves the interval $[(1-b)a, (1+b)a]$. In this way, n^D is set at 1 in the steady state as described above.

[12] To see this, consider the two extreme cases: When $\widetilde{c}$ is at its lowest possible value, namely $(1-b)a$, zero firms will locate abroad as none has a lower fixed cost than the threshold value. If on the other hand the threshold value equals the maximum value of the interval, namely $(1+b)a$, then all firms in $i \in [0, 2]$ locate abroad.

2.3 The FDI-export link

There is an extensive literature investigating the effect of foreign investment on export demand in the host country. The general finding is that the former tends to generate increases in the latter (Kastratović, 2020). Several pathways for such a causal relationship between foreign investments and export demand have been identified, including the direct effect of establishing foreign affiliates with the objective of exporting to markets outside the host country (export platforms), but also indirect effects arising from the positive information externalities affecting host country firms through the presence of foreign firms, imitation and demonstration effects, skill acquisition, improvements in general infrastructure as well as increased competition; see e.g. Jones and Dei (1983), Kojima et al. (1975) Aitken et al. (1997), Clerides et al. (1998), Greenaway et al. (2004) and Tintelnot (2017).

We do not attempt to account for these transmission channels in our model, but include in our model a reduced-form causal relationship between foreign investment (due to firms deciding to locate in Norway) and export demand to proxy these transmission channels. As we will show, only by including this proxy are we able to account for the empirically observed response of intensive- and extensive-margin investment to corporate tax cuts. While we do not explicitly target the elasticity of exports with respect to FDI, we verify that the outcome is consistent with Norwegian historical data.

Specifically, and going beyond the setup of the original NORA model, we assume that demand for exports is a function not only of prices for Norway's export goods, the exchange rate and the income of trading partners, but also of the number of firms producing in Norway. In our model, export demand is thus given by:

$$X_t = (1 + \xi_X(n_t^D - 1))(P_t^x)^{-\eta_{TP}} Y_t^{TP}, \tag{6}$$

where P_t^x is the price of Norway's exports expressed in foreign currency and Y_t^{TP} measures the income of Norway's trading partners. The parameter η_{TP} captures the elasticity of substitution for Norwegian exports. Abstracting from the first term, this export demand function follows from the optimal decisions of foreign export good purchasers and is standard in the literature. However, in our model, this export demand is subject to a further term that captures how many foreign firms relocate to Norway, with ξ_X governing the sensitivity of export demand to these relocation decisions. The choice of functional form is inspired by empirical specifications linking the amount of foreign investment to exports, found for example in O'Sullivan (1993).[13] In the initial calibration of the model, where $n^D = 1$, export demand collapses to the standard formula. As firms move to Norway and n^D increases beyond unity, these firms generate additional export

[13] Note that taking the logarithms of both sides of equation 6 yields $\ln X_t \approx \ln Y_t^{TP} - \eta_{TP} \ln P_t^x + \xi_X(n_t^D - 1)$, which roughly corresponds to Equation 3 in O'Sullivan (1993).

demand for goods produced in Norway. The larger the sensitivity parameter ξ_X, the larger the increase in export demand following relocation. The parameter can be interpreted as measuring how much more export-oriented relocating firms are than the average incumbent Norwegian firm.[14] Note, however, that we do not explicitly differentiate between the export demands that incumbent and newly located firms face. Instead, there is an increase in aggregate export demand from which all firms producing in Norway benefit equally.

2.4 The user cost channel

In the following, we introduce the problem faced by a firm i that decides to locate in Norway and present its first order conditions. In modeling the financing decisions of such firms and their tax bases, we add considerably more detail than for those that produce abroad, in order to adequately determine the intensive margin response. The production function of firm i is given by the Cobb-Douglas function

$$Y_t(i) = (K_t(i))^{\alpha}(N_t(i))^{1-\alpha}, \tag{7}$$

where $Y_t(i)$ denotes the output of firm i, $K_t(i)$, and $N_t(i)$ are the capital and labor inputs in the production process, and α is the output elasticity of capital. The demand faced by individual firms is given by

$$Y_t(i) = \left(\frac{P_t^Y(i)}{P_t^Y}\right)^{-\epsilon} Y_t.$$

Thus, each individual firm takes into account that the demand for its good $Y_t(i)$ depends on the price it sets $P_t^Y(i)$ relative to the aggregate price $P_t^Y = (\int_0^1 P_t^Y(i)^{1-\epsilon} di)^{\frac{1}{1-\epsilon}}$. The produced good is combined with imports and the good from the second domestic sector to generate final goods. The firm's capital stock evolves according to the following capital accumulation equation

$$K_{t+1}(i) = I_t(i) + (1-\delta)K_t(i), \tag{8}$$

where $I_t(i)$ denotes investment, and δ is the capital depreciation rate. Firms borrow money to finance their operations by issuing bonds B_t. Nominal firm debt accumulates according to

$$P_t B_t(i) \quad = \quad P_t BN_t(i) + P_{t-1}B_{t-1}(i), \tag{9}$$

where P_t is the nominal price in the economy, $BN_t(i)$ denotes the real value of new domestic borrowing. We define the debt-to-capital ratio as $b_t(i) = \frac{B_t(i)}{\lambda_t^K(i)K_t(i)}$. Here $\lambda_t^K(i)$ is the shadow

[14] If $\xi_X = 1$, then export demand simply increases linearly with the number of firms in Norway. If $\xi_X > 1$, as will be the case in our calibration, firms relocating to Norway tend to be more export-oriented than those already in Norway. Conversely, firms that are more export-oriented tend to leave the country first in the case of corporate tax hikes. Note that we have numerically checked that export demand cannot become negative for a realistic calibration and tax shock size.

price of capital as defined below. The cost of borrowing is given by $(1+R_{t-1})RP^B_{t-1}(i)$-1, where $RP^B_t(i)$ represents a risk premium, which comes on top of the nominal risk-free interest rate R_t and which increases with borrowing, as captured by the firm's debt-to-capital ratio. In particular, we assume that

$$RP^B_t(i) = \exp^{\xi_B(b_t(i)-\beta_B)}, \tag{10}$$

with ξ_B capturing the responsiveness of the risk premium to the debt-to-capital ratio and β_B representing a parameter calibrated to ensure that NORA matches the empirical debt-to-capital ratio in Norwegian firms.[15]

The total before-tax profit is then given by

$$\Pi_t(i) = \underbrace{P^Y_t(i)Y_t(i)}_{\text{sales}} - \underbrace{(1+\tau^{SSF}_t)W_tN_t(i)}_{\text{labor costs}} - \underbrace{((1+R_{t-1})RP^B_{t-1}(i)-1)\frac{B_{t-1}(i)}{\pi_t}}_{\text{interest on dom. borrowing}}, \tag{11}$$

where W_t is the economy-wide wage rate, and τ^{SSF}_t is the social security tax paid by firms.[16] The corporate profit tax base is then given by

$$TB^{\Pi}_t = \Pi_t - \delta_\tau K^\tau_t - TD.$$

A depreciation allowance $\delta_\tau K^\tau_t$ is deductible from profits, where the tax depreciation rate is given by δ_τ, and for tax purposes the cost basis of capital stock evolves according to the equation[17]

$$K^\tau_{t+1} = \frac{P^I_t I_t}{\pi_{t+1}} + \frac{(1-\delta_\tau)K^\tau_t}{\pi_{t+1}}, \tag{12}$$

where $\pi_t = P_t/P_{t-1}$ is the inflation rate and P^I_t the relative price of the investment good. Thus, in contrast to the capital accumulation equation (8), the tax cost basis of the capital stock (the taxable capital stock) depreciates at a different rate and measures the accumulated nominal value of investments, rather than the investment volume.[18] The term TD captures an allowance for corporate profits and is calibrated such that the tax base profits in steady state are in line with data. Implicit in this definition of the tax base and in line with the Norwegian tax code is that

[15] The firm payments associated with the risk premium, i.e. the debt servicing costs in excess of the bank's lending rate, are assumed to be redistributed in a lump-sum fashion to the Ricardian household.

[16] Note that equation (11) represents profits after interest payments, which in accounting is typically referred to as earnings before income taxes (EBT).

[17] Note that some models abstract from tracking the cost basis of capital stock for tax purposes and instead apply the tax depreciation rate to the productive capital stock. If the tax depreciation rate is higher (lower) than the economic depreciation rate, such an approximation would overestimate (underestimate) the value of future depreciation allowances and bias the effect of the depreciation channel, which is discussed later.

[18] A more intuitive way of expressing the equation for cost basis of capital is $K^{\tau,NOM}_{t+1} = P_t P^I_t I_t + (1-\delta_\tau)K^{\tau,NOM}_t$, where $K^{\tau,NOM}_t = P_t K^\tau_t$ is the nominal cost-basis of capital stock for tax purposes. Thus, the nominal value of the capital stock accumulates with the nominal value of investments. However, since the whole model uses the CPI as its numeraire, we keep track only of the taxable capital stock deflated by the CPI. This, however, has no bearing on our results.

borrowing costs are considered to be a deductible expense for tax purposes while new investments financed by equity are not (Sørensen, 2004, Södersten, 2020). The shareholder's free cash flow is then either retained to finance net investment, or used to pay dividends to shareholders or taxes to the government. Hence, it holds that

$$\Pi_t(i) = \Pi_t^R(i) + DIV_t(i) + TB_t^{\Pi}(i)\tau_t. \tag{13}$$

where $\Pi_t^R(i)$ is the cash flow retained after paying out dividends and taxes. Investment is thus financed by the retained cash and new borrowing, such that $P_t^I I_t(i) = \Pi_t^R(i) + BN_t(i)$. Thus, a marginal investment is assumed to be partly debt- and partly equity-financed. As we show further below, the share of each financing source is determined by firms' profit maximization.

The firm's value is equal to the present discounted value of future dividends

$$V_t(i) = \sum_{j=1}^{\infty} \Delta_{t+j}^{DIV} DIV_{t+j}(i),$$

where the cumulative dividend discount factor in period $t+j$ is given by $\Delta_{t+j}^{DIV} = \prod_{i=0}^{j-1} \frac{1}{1+r_{t+i}}$ and r_t is the real market interest rate. The real market interest rate is a function of the household-level after-tax interest rate on deposits, which reflects household's discounting of future cash flows, and ultimately depends on the risk-free interest rate set by the central bank, inflation, the household ordinary income tax rate (τ_t^{OIH}) and an equity premium (RP_t), i.e.[19]

$$r_t = \frac{1}{\pi_t} + \frac{(1-\tau_t^{OIH})R_t}{\pi_t} - 1 + RP_t.$$

The real market interest rate is, however, not a function of the dividend tax rate. This is due to an allowance for shareholder equity (ASE), which results in only the equity premium being taxed and thus does not introduce any distortion with respect to investment decisions. While this is not the focus of the present paper, we provide a short note on this neutrality result in the appendix, Section F. A formal proof, which is also applicable to our framework, is provided in Södersten (2020).

We assume that firms face three types of adjustment costs: price, investment, and borrowing adjustment costs. These costs improve the empirical fit of the model and are calibrated in the original NORA model to match the Norwegian business cycle moments. In the following equilibrium conditions, we abstract from these adjustment costs. The technical appendix and the simulation results do take these costs into account, however.

[19] See the appendix, Section F.

The maximization problem of firms The decision variables of firm i are the amount of labor it wants to employ $N_t(i)$ given the wage rate in the economy, the price it wants to charge for the good it produces $P_t^Y(i)$, the amount of investment $I_t(i)$ it wants to undertake, and the amount of new borrowing $BN_t(i)$ it needs to carry out that investment. The firm chooses the optimal value of these variables in order to maximize its share price, taking into account constraints related to how physical capital (see equation 8), taxable capital (see equation 12), and firm debt (see equation 9) accumulates, and the need to satisfy the demand that materializes at the prevailing price using the production technology in equation (7). We arrive at equations characterizing the behavior of all firms that have decided to produce in Norway.

The first-order conditions for ***labor*** and ***prices*** are derived in detail in appendix C and are left out here for brevity. In line with standard DSGE models, firms choose the amount of labor they want to employ in such a way that the wage equals the marginal product of labor. The price of output is set as a mark-up over the value of one unit of production, subject to price adjustment costs.

The first-order condition on ***new borrowing***, excluding adjustment costs, is given by $\lambda_t^B = -1$, where λ_t^B is the Lagrange multiplier on new borrowing. Hence, a marginal unit of new borrowing decreases the value of the firm by one unit. New borrowing, however, also allows the firm to invest, which has positive effects on the value of the firm. Keeping the simplifying assumption of no adjustment costs on new borrowing, the envelope condition for the level of debt B_t captures this trade-off between the costs and benefits of borrowing:

$$\frac{(1+r_t)\pi_{t+1}-1}{1-\tau_{t+1}} = (1+R_t)RP_t^B(1+\xi_B b_t)-1. \tag{14}$$

The right-hand side of equation (14) captures the marginal cost of borrowing. It depends on the risk-free interest rate, the risk premium on firm borrowing RP_t^B, and the marginal increase in the risk premium $\xi_B b_t$ caused by an increase in the debt-to-capital ratio; see equation (10). Importantly, the term $RP_t^B(1+\xi_B b_t)$ increases with the debt-to-capital-ratio b_t. The left-hand side of equation (14) captures the cost of equity financing.[20]

Two points should be mentioned about this result. First, the share of debt b_t is a function of the difference in the (required pre-tax) market return and the risk-free rate R. The lower the risk-free rate relative to the cost of equity financing, the more firms will borrow to finance investment, until the point at which the risk premium (increasing with debt) restores the balance between the cost of borrowing and the cost of equity. Importantly, this implies that the marginal investment is always financed by both debt and equity.[21]

[20]Note that the cost of equity-financing term, usually captured by $\frac{r}{1-\tau}$, is expressed in nominal terms here as also the right-hand side, the cost of debt, is given in nominal terms.

[21]Consider an investment project that is solely financed by retained earnings. This would lead to a fall in the debt-to-capital-ratio b_t as the capital stock increases, while debt levels remain constant. This in turn would

Second, a change in the corporate tax rate directly impacts the balance between debt and equity. Cutting the tax rate lowers the required return on equity and thereby reduces its cost as an investment financing instrument. While the cost of debt financing is ex-ante independent of the corporate tax rate, in general equilibrium the fall in equity financing costs necessitates a fall in the cost of debt financing, which can only be achieved by a reduction in b_t, and ultimately in debt. Hence, a corporate tax cut shifts the burden of financing away from debt towards equity, to an extent that depends on the elasticity of the debt risk premium to changes in b_t. A consequence of this shift is also a broadening of the tax base as interest costs, now reduced, are deductible from the corporate profit tax base.[22]

The first-order condition for ***investment***, excluding investment adjustment costs, is given by

$$\lambda_t^K + \lambda_t^{K^\tau} \frac{P_t^I}{\pi_{t+1}} = P_t^I. \tag{15}$$

Thus the shadow price of the real and taxable capital stock combined is equal to the price of the investment good. In other words, the capital stock is expanded until the value added to the firm by a marginal unit of capital, taking into account both the value increase through higher productive capital but also a higher taxable capital stock (which generates depreciation allowances), begins to fall below the price of investment. The equations for the shadow prices of the two capital stock measures are given by

$$\lambda_t^K (1 + r_t) = \lambda_{t+1}^K (1 - \delta) + \lambda_{t+1}^Y \alpha \frac{Y_{t+1}}{K_{t+1}}, \tag{16}$$

$$\lambda_t^{K^\tau} (1 + r_t) = \frac{\lambda_{t+1}^{K^\tau} (1 - \delta_\tau)}{\pi_{t+2}} + \tau_{t+1} \delta_\tau. \tag{17}$$

The shadow price of the capital stock at time t is given by its future shadow price adjusted for physical depreciation and the value generated by the capital in the production process. Similarly, the value of the taxable capital stock is given by its future shadow price adjusted for depreciation at the tax-relevant rate plus the cash flow generated by the tax depreciation shield.

lower the cost of borrowing below the cost of equity and the firm would thus not minimize its cost of funding. Conversely, an investment project solely financed by debt would bring the profit-maximizing condition (14) out of balance by increasing the cost of borrowing beyond the cost of equity. Marginal investment is thus always going to be financed partly by debt and partly by equity, thereby preserving the equality of the respective marginal funding costs.

[22] Hypothetically, one could also construct a model in which marginal investment is financed by debt only, so that a reduction in corporate taxes would not affect investment decisions. However, we have opted for the more realistic option of allowing both financing channels to play a role, with the firm being able to choose optimally between them.

2.4.1 User cost of capital

Given the first-order condition for investment and the shadow prices for capital, we can derive the user cost of capital P^K as

$$P_t^K = P^I \left[\frac{r_t}{1-\tau_{t+1}} + \delta + \frac{\tau_{t+1}}{1-\tau_{t+1}} \left(\delta - \frac{\delta_\tau}{\pi_{t+1}} \right) + \frac{\lambda_{t+1}^{K^\tau}}{(1-\tau_{t+1})\pi_{t+2}} \left(1 - \delta - \frac{1-\delta_\tau}{\pi_{t+1}} \right) \right]. \quad (18)$$

As shown in the appendix, in the optimal case the user cost of capital equals the marginal product of the next period's capital stock. An increase in the user cost of capital will thus imply an increase in the optimal marginal product of capital. Due to the concavity of the production function, this in turn necessitates a fall in the capital stock. Thus an increase in the user cost of capital will induce firms to reduce investment, while a drop in the user cost will boost investment.

The user cost of capital consists of three components. The first component, which we call the required return channel, relates to the condition that investments need to earn at least an after-tax return equal to the real market interest rate r, otherwise these resources would be invested elsewhere in the market. This implies that the pre-tax return, including compensation for capital depreciation, needs to equal $\frac{r}{1-\tau} + \delta$. A lowering of the corporate income tax rate, τ, will lower the required pre-tax return, so that the user cost of capital falls. Such an effect is consistent with models that assume retained earnings to be the marginal source of financing (King, 1974). It is important to note, however, that the firms in our model make an endogenous choice between retained earnings and financing through borrowing (recall equation 14) and thus use a mix of both financing sources. Simultaneous use of two funding sources implies that the two rates of return adjust according to equation (14). In contrast, in models with purely debt-financed investment (Sandmo, 1974, see case with $k = 0$), the borrowing rate is independent of the tax rate, so that this effect on the user cost of capital is absent. The required return channel may also be independent of the tax rate in the case of tax systems that allow for a tax deduction for the cost of equity, i.e. so-called Allowance for Corporate Equity (ACE) systems. Norway, however, has introduced an Allowance for Shareholder Equity (ASE) tax system, which instead grants an allowance for dividend and capital gains income at household level. While this results in neutrality of the dividend tax rate with respect to the user cost of capital (see appendix F), it does not neutralize the effect of the tax on corporate profit on investment decisions (see appendix G). This is because the ASE system does not compensate for the additional pre-tax return required by corporations to earn a given market return after paying taxes on corporate profit. This additional required return prevents investment at the margin that would otherwise have happened in the absence of the corporate profit tax, thereby distorting investment decisions.

In line with Sandmo (1974), the second component relating to the depreciation allowance adjusts the required return when there is a wedge between the economic and tax depreciation rates. As the latter is applied to the nominal value of the taxable capital stock, it is divided by the inflation rate to make it comparable to the real economic depreciation rate δ. To understand the importance of this wedge, let us first consider the case where it is absent, i.e. $\delta = \delta_\tau/\pi_{t+1}$. In this case (and assuming that the taxable capital stock is equal to the physical capital stock), the value of the tax depreciation allowance equals exactly the cost of depreciated capital, such that effectively only the return after depreciation is subject to the corporate profit tax. The corporate profit tax then does not affect the firm's user cost of capital and thus investment decisions beyond the required return channel. However, if the real depreciation rate is larger than the tax depreciation rate, i.e. $\delta > \delta_\tau/\pi_{t+1}$, it is costly for the firm to hold capital from a tax perspective since the tax then effectively also taxes depreciating capital. This is reflected by the fact that this second term is then positive, increasing the user cost of capital relative to the case of a neutral tax depreciation rate. If, on the other hand, the tax depreciation rate is larger than the real depreciation rate, which is the case for Norway as we argue later, then the firm has a tax benefit from holding capital and the user cost of capital is lower than in the neutral case.

Finally, the third component (not present in Sandmo's contribution) captures the fact that a potential wedge between the two depreciation rates implies that the physical capital stock and the taxable capital stock depreciate at different speeds[23]. The neutral case for this term is given when $1 - \delta = (1 - \delta_\tau)/\pi_{t+1}$. Under this condition, and as is evident from comparing equation (8) with (12), both capital stocks depreciate at identical rates and there is no effect on the user cost of capital through this channel. However, when δ_τ is sufficiently larger than δ, so that $1 - \delta > (1 - \delta_\tau)/\pi_{t+1}$ holds, this differential depreciation will tend to increase the user cost of capital. This is because the taxable capital stock generates income to the firm through the tax depreciation allowance (also captured by the fact that $\lambda_t^{K^\tau} > 0$ as shown in the Appendix). Hence, the faster this stock depreciates, the lower the present discounted value of tax depreciation allowance, which implies a lower tax benefit from holding capital. This third term is of course closely linked to the second, as both derive from the differential depreciation rates and can best be viewed as dampening either the positive or the negative effect of the second term. The joint effect of the two terms can be seen as roughly equivalent to an interest-free loan granted by the tax authority to the company when tax depreciation exceeds economic depreciation, and vice versa when economic depreciation exceeds tax depreciation, see Södersten (1982).

2.4.2 The passthrough of a corporate tax cut: theoretical predictions

In the following, we analytically determine the partial equilibrium elasticity of intensive-margin investment with respect to a change in the corporate profit tax rate. To simplify the analysis, we

[23] In Sandmo (1974) it is assumed that capital markets are perfect in the extreme sense that capital goods can be bought and sold in any amount at the same price and that adjustment costs are either insignificant or that they are simply proportional to the amount of gross investment, so that these costs can be interpreted as included in capital goods prices.

consider only the long-run elasticity, and thus only steady-state effects. As derived in Appendix D, we can then show that the long-run semi-elasticity of the user cost of capital with respect to corporate income tax is given by

$$\epsilon_\tau^{P^K} = \frac{\partial P^K}{\partial \tau}/P^K = \frac{1}{1-\tau}\frac{(r+1)\pi - 1}{(r+1)\pi - 1 + \delta_\tau(1-\tau)} > 0.$$

Assuming $\frac{\partial N}{\partial \tau} = 0$, the semi-elasticity of investment with respect to corporate income tax is given by

$$\epsilon_\tau^I = \frac{1}{\alpha - 1}\epsilon_\tau^{P^K} < 0. \tag{19}$$

Thus this analytical expression allows us to determine the effect of investment on the intensive margin given a corporate profit tax cut, subject to the following caveat: The expression is based on a partial equilibrium view, as we ignore the effects of the corporate tax cut on labor inputs and general equilibrium effects on firm demand due to changes in aggregate demand, most importantly through changes in export demand caused by the relocation of firms. In our result section, we will compare the implications of this formula on the intensive margin of investment with the actual full simulation results in order to understand the general equilibrium effects on the intensive margin.

Three important conclusions can be drawn from expression (19). First, the semi-elasticity of intensive-margin investment (in absolute terms) increases with the market interest rate r. This shows that investment is more strongly suppressed in a high-interest environment, implying particularly effective corporate tax cuts. Conversely, a low level of market interest rates reduces the effectiveness of tax cuts at boosting investment. Second, the elasticity falls as the tax depreciation rate rises. This is because at high values of the tax depreciation rate, the value of the tax depreciation shield is relatively high. A reduction in tax rates will thus reduce not only the required return, but also the value of the tax shield. The higher the tax depreciation rate, the more important the latter effect. Third, at already high values of τ, a tax change has stronger implications for the user cost of capital than at lower values of τ. As with the argument made for r, this shows that investment is more strongly boosted when it was distorted more strongly pre-reform.

Note that elasticity is always negative, since $r \geq 0, \delta_\tau \geq 0$ and $\tau \leq 1$.[24] Hence, in contrast to Sandmo (1974), our model suggests that a cut in the corporate profit tax rate will lower the user cost of capital and increase intensive-margin investment independently of the difference between the tax and economic depreciation rates. An important difference from Sandmo (1974) is that we additionally take into account the faster depreciation of the taxable capital stock as opposed to the physical one, see appendix E for more details.

[24] We assume that long-run inflation is positive, i.e. $\pi > 1$.

3 Data and Calibration

We build on the calibrated version of NORA as published in Aursland et al. (2020).[25] In this section, we will only discuss the calibration of the new elements in this paper, including our revised calibration of the interest rate, the values used for physical and tax depreciation rates and the calibration of the parameters governing firm behavior.

3.1 Calibration of market returns

We base our calibration of the market return rates on previous studies by Norway's central bank, Norges Bank, and the Mork Commission. Norges Bank has recently estimated the neutral real interest rate to be between 0 and 1 %; see Norges Bank (2018). The neutral real interest rate is the real interest rate that is consistent with stable developments in commodity prices. Given an inflation target of 2 %, the neutral nominal interest rate is then between 2 and 3 %. We chose 2.5 %. In the model we calibrate the nominal interest rate by choosing the household's discount factor accordingly. Given a corporate bond risk premium of 1.5 % and an equity premium of 3 %, the nominal corporate bond and nominal stock market return are set to 4 and 5.5 %, respectively. The magnitude of these premiums is taken from the assessment of the Mork Commission, which was appointed to assess the equity share of the Government Pension Fund Global; see NOU (2016). The equity premium is calibrated by assuming that households holding stocks pay financial fees that increase the required return on stocks beyond the risk-free return on bank deposits. Corporate bond returns are calibrated by choosing the sensitivity of the corporate bond risk premium ξ_B accordingly, as the latter determines the size of the firm risk premium and thus the wedge between interest rates paid by corporates relative to risk-free interest rates.

3.2 The aggregate real and tax depreciation rates

Our macroeconomic model holds one aggregate capital asset. To calculate the aggregate real and tax depreciation rates from microeconomic data, we follow the procedure outlined in Oulton and Srinivasan (2003), where the aggregate depreciation rate is defined as the weighted average of asset-specific depreciation rates, and where the weights are based on the nominal capital stock for each capital object. We base our aggregate real depreciation rates on the findings in Barth

[25]NORA is calibrated to the Norwegian mainland economy at the quarterly frequency in a two-step procedure. First, a subset of the parameters that determine the steady state of NORA are chosen such that the model's deterministic steady state replicates a number of long-run empirical moments, while the remaining steady-state parameters are set either according to microeconomic evidence or by following related models. Second, we chose values for the parameters, which only affect the dynamic behavior of the model, in order to obtain a good match with VAR studies on the Norwegian business cycle.

Table 1: Real and tax depreciation rates. Per cent. Annual rate. 2019

	Weight	Real depreciation	Tax depreciation
Aggregate depreciation rates		10.3	14.8
Buildings	50.8	3.9	2.0
Transportation vehicles	11.8	15.9	22.0
Machinery	25.3	15.3	20.0
R&D, intangible assets, etc.	7.6	27.4	71.2
Boats and airplanes	4.5	9.8	13.0

Real depreciation rates are based on figures from the Norwegian National Accounts and Barth et al. (2017). Tax depreciation rates are taken from https://www.skatteetaten.no/en/rates/depreciation-rates/.

et al. (2017). They conducted a survey of Norwegian firms on their perception of the expected economic service life of various fixed capital assets as well as their assessment of depreciation profiles. Table 1 shows the real depreciation rates based on the results from this survey and the rates that are currently used in the National Accounts. Table 1 also shows the corresponding tax depreciation rates for 2020 as given by the Norwegian tax authorities for the following capital types: buildings, transportation vehicles, machinery, R&D, intangible capital, etc., and boats and airplanes. With the exception of buildings, the pattern seems to be that tax depreciation rates are somewhat higher than real depreciation rates. For R&D, intangible capital etc., the difference is high and reflects the fact that R&D can be expensed immediately according to Norwegian tax laws. In aggregate, the real annual depreciation rate we use in the model is 10.3 percent, which is 4.5 percentage points lower than the aggregate tax depreciation rate of 14.8 %.

3.3 The calibration of firm behavior parameters

Table 2 lists the parameters governing firm behavior. We set the corporate profit tax rate abroad, τ^F, as the average of effective average tax rates across OECD countries and 2018-2020 as provided by OECD (2020).[26] The rate of depreciation is set at the standard literature value of an annual 8%, which equals 2.06% per quarter. Analogously, we set the capital elasticity at 0.33 following the literature convention.

Next in the table are the three remaining parameters that govern the behavior of domestic firms. The value for the capital elasticity is set to match the empirical capital to output ratio in Norway, while the elasticity of substitution across differentiated goods follows Norges Bank DSGE Model Nemo, see Kravik and Mimir (2019). The risk premium parameter on firm borrowing is set to match the corporate bond risk premium, as explained before.

[26]Note that this measure implicitly captures country-specific allowance rules for capital depreciation, so that we refrain from explicitly modeling allowance rules abroad.

Table 2: Parameters governing firms' location decisions

Parameter	Description	Value
τ^F	Corporate profit tax rate abroad	20.5%
δ^F	Depreciation rate abroad (quart.)	2.06%
α^F	Capital elasticity abroad	0.33
α	Capital elasticity at home	0.25
ϵ	Elasticity of substitution across domestic output	6
ξ_B	Risk premium parameter on firm borrowing	0.015
b	Spread in fixed mobility costs	0.876
ξ_X	Sensitivity of export demand	2.87
ρ^n	Speed at which firms realize investment location	0.04

Not provided in the table is the foreign real market interest rate, r_t^F, which we set identical to Norway's real market interest rate. The productivity parameter A^F is set such that the output of firms abroad is similar in size to the output of firms in Norway. This assumption has no bearing on the results but ensures smooth numerical convergence.[27]

The spread in fixed mobility costs governs the amount of firm relocation, while the sensitivity of export demand determines the extent to which the relocation stimulates exports. We calibrate these two parameters jointly to match the extensive margin investment behavior using the international meta study by Mooij and Ederveen (2008), and the elasticity of exports with respect to foreign direct investment based on the study for European countries by Popovici (2018). Mooij and Ederveen (2008) find that the semi-elasticity of the number of foreign firms with respect to the effective average tax rate (EATR) on corporate profits is -3.25. They obtain the corresponding semi-elasticity of the tax base by multiplying the latter number by an estimate of the share of internationally mobile capital (20 %), which yields a semi-elasticity of the corporate tax base equal to -0.65 (=-3.25*0.2).[28] Note that EATR differs from the statutory corporate tax rate. Specifically, as defined in Devereux and Griffith (2003), we calculate the rate as $EATR = (PV^* - PV)/PV^*$, where PV (PV^*) is the present value of the next period's dividend payoff including (excluding) taxes. Through simulation, we find that when the corporate tax rate in NORA decreases from 28 % to 27 %, the $EATR$ decreases by 0.9 percentage point, from 27.0 % to 26.1 percent. Hence our target for the extensive margin effect on the corporate tax base for a 1 percentage point cut in the statutory tax rate becomes $\hat{\epsilon}_{TB}^{ext} := 0.9 \times 0.65\ \% = 0.585\ \%$.

[27] A^F only governs the scale of output of those firms that could potentially move to Norway, not of all firms in the global economy. In contrast, the size of the total global economy is assumed to be considerably larger than Norway's, in line with our small open economy assumption.

[28] There is considerable uncertainty in both factors. Measured in terms of foreign direct investment relative to overall investment, the share of internationally mobile capital in Norway is roughly 15 %, while based on foreign ownership data, the share would come to well over 20 %. The Swedish Ministry of Finance has used an estimate of 25 %. Choosing a middle way strategy, we follow Mooij and Ederveen (2008) and choose -0.65 as our target.

Popovici (2018) gives an average estimate for the elasticity of exports with respect to the FDI in European countries, $\hat{\epsilon}_X^{FDI} = 0.2$. Within the model, we calculate ϵ_X^{FDI} as the percentage change in exports divided by the percentage change in FDI stock when the corporate tax rate is reduced by one percentage point.

Our calibration strategy is as follows: We use the simplex optimization algorithm to find the values which minimize the loss function $(\epsilon_{TB}^{ext} - \hat{\epsilon}_{TB}^{ext})^2 + (\epsilon_X^{FDI} - \hat{\epsilon}_X^{FDI})^2$, where ϵ_{TB}^{ext} is the simulated semi-elasticity of the extensive margin effect on the tax base with respect to the EATR, and ϵ^{int} is the semi-elasticity of intensive margin investment with respect to the EMTR. The corresponding variables with hats, introduced above, represent the empirical targets. The loss function is minimized at $b = 0.876$ and $\xi_X = 2.87$.

Finally, we choose $\rho^n = 0.04$ so that firms' moving decisions are initially slowed down, but the number of relocated firms converges close to the long-run value no later than at 25 years. This choice of dynamics is informed by empirical evidence (Wijeweera and Mounter, 2007, Wijeweera and Clark, 2006), indicating that FDI responses to corporate tax reforms only become significant after 1-4 years.[29]

4 Results

In this section, we discuss the simulation results for a 1 percentage point corporate tax cut. We first analyze the channels whereby the effects of the tax cut feed through to investment and other macroeconomic variables and then discuss the sensitivity of the results to various model assumptions and calibration choices.

4.1 The transmission of a corporate tax cut to the macroeconomy

Effect on investment

In Figure 2 we show the response of investment and output (as % increase relative to the initial steady state) to a permanent cut in the corporate profit tax rate from 28 % (the pre-reform corporate tax level in Norway) to 27 %. We first focus on the benchmark model (blue, solid line), which incorporates the firm relocation channel. The 1 percentage point cut in the tax rate causes a long-run increase in investment of about 0.62 %. This occurs through three channels. First, firms producing in Norway face a lower user cost of capital and ceteris paribus find it optimal to

[29]Given our calibration, about 15% of those firms that eventually move, do so within one year of a change in corporate taxation.

expand their capital stock, as predicted by intensive margin partial equilibrium results in 2.4.1. Second, as the tax cut induces firms to locate to Norway, see below, incumbent firms face more domestic competition, which is mitigated by the fact, that the foreign relocating firms stimulate export demand also for incumbent firms, see sections 4.2 and 4.3 further below. These general equilibrium effects also affect the intensive margin by shifting the demand that firms in Norway face. Taken together, these effects are illustrated by the plot of the intensive margin, capturing the change in investment per firm.[30] Due to investment adjustment costs, the accumulation of the now higher capital stock occurs slowly, with the new steady state being reached after around 15 years. Third, a number of firms originally producing abroad see an increase their after-tax profits if they relocate to Norway, prompting them to move production. This is illustrated by the plot of the extensive margin, which shows the increase in the number of domestically-producing firms and the additional investment resulting from these relocations. When firms relocate, we assume that a share of their capital is transferred from abroad, while the remaining share is produced and installed in Norway.[31] However, this process occurs slowly, as relocation is a sluggish process (see equation 5). In the long-run, once the optimal capital stock has been reached, the extensive margin is determined by the continuous investment of those newly relocated firms necessary to sustain their capital stock.

Overall, the long-run increase in investment of 0.62 % is explained by about 0.03 % higher investment per firm (intensive margin), and 0.59 % higher investment due to relocation (extensive margin). The magnitude of the long-run response of the extensive margin follows from our calibration strategy of matching Mooij and Ederveen (2008); see the calibration section 3.[32]

[30] Total investment is given by $n_t^D I_t$. We measure the intensive margin as the change in I_t (investment per firm in Norway) and the extensive margin as the change in n_t^D (number of firms located in Norway).

[31] The details in this regard are not important for the results and only affect the initial response of foreign investment. We assume that 20 % of the initial capital stock is produced using Norwegian resources, and the rest is transferred or bought from abroad using the existing real capital or proceeds thereof.

[32] The long-run intensive margin response is considerably smaller than the partial equilibrium estimate in Mooij and Ederveen (2008). One reason to that is that the after tax market interest rate depends on equity premium, which in turn decreases with increasing corporate tax rate. That effect is relevant also in the absence of firm relocation. Another important effect is that the foreign investment crowds out a significant part of the domestic investment response. This intensive margin general equilibrium effect is elaborated further in section 4.2.

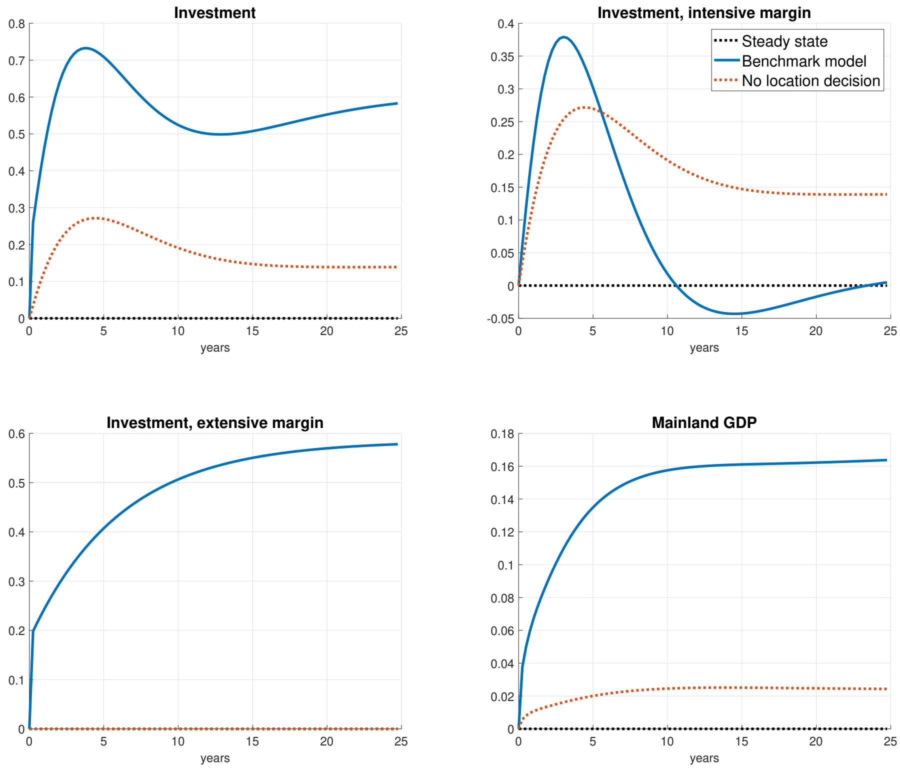

Figure 2: Simulation results for a corporate tax cut by 1 pp. Per cent deviation from baseline (initial steady state)

Further macroeconomic effects

We show the response of other main macroeconomic variables in Figure 3. In the benchmark model, firms moving to Norway induce higher export demand from abroad (equation 6). This leads to a long-run rise in exports of 0.6 %. This is qualitatively consistent with the empirical literature that finds a positive effect on exports following foreign direct investment, as reviewed in the meta study Kastratović (2020). This issue is discussed further in Section 4.3. Total output in Norway, see figure 2, increases as investment and exports expand.

As the profitability of the manufacturing sector improves and employment increases due to the investment boom, wage bargaining between the unions and the manufacturing sectors leads to higher wages, which in turn pushes up domestic consumption. Consequently, the corporate profit tax cut does not solely benefit the corporate shareholders. According to our estimates, 39% of the total tax relief effect goes towards increased dividends for Norwegian or foreign corporations. About half, 48%, goes to wage increases for the employed, and 13% goes to hiring unemployed

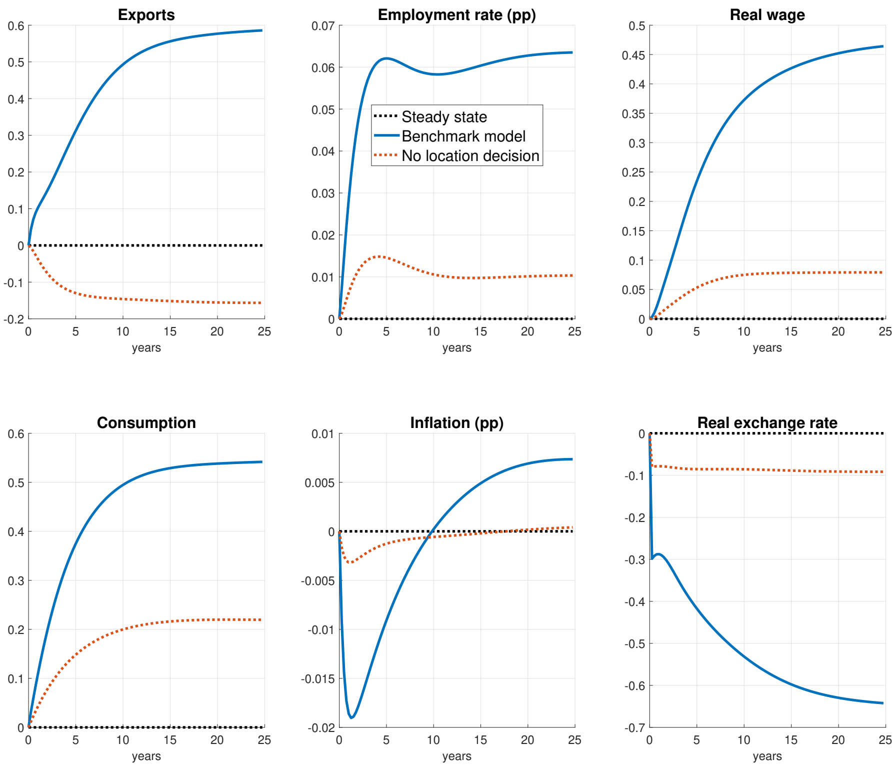

Figure 3: Simulation results for a corporate tax cut by 1 pp. Per cent deviation from baseline unless stated otherwise

persons or those who are initially outside the labor force.[33] These results are broadly in line with numerous studies that show that a significant portion of corporate tax is ultimately paid by workers.[34]

In line with Wijeweera and Mounter (2007), the real exchange rate initially appreciates following the reduction in the corporate tax rate. This occurs because the Norwegian economy initially attracts investment from abroad. Inflation initially slows down due to the appreciation of the real exchange rate, but in the medium-run it increases as aggregate demand and wages increase. Following a standard Taylor rule, the interest rate (not shown) increases in response to rising inflation.

[33]The benefit to shareholders is measured as the long-run increase in total (domestic and foreign) dividends. The benefit to the employed is calculated as the long-run aggregate increase in the wage bill among those who had already been employed pre-reform. The benefit to the unemployed and those outside the labor force is calculated as the change in their aggregate labor/transfer income. The total effect of the tax relief is then defined as the sum of all three effects.

[34]The studies include Arulampalam et al. (2012), Felix (2007), Gravelle and Smetters (2006), Harberger (2008), Hassett and Mathur (2006), Mutti and Grubert (1985), and Randolph (2006) see Table 13.15 in NOU (2014) for an overview.

Debt vs equity financing

In many tax systems, such as in Norway, debt is deductible from the corporate tax base while the cost of equity is not. This favorable tax treatment of debt gives rise to an erosion of the corporate tax base and a bias towards the use of debt financing, the magnitude of which increases with the corporate tax rate. Our model is able to capture this distortion by keeping track of the debt-to-capital ratio. A reduction in the corporate profit tax causes the cost of equity to fall. Firms reduce their debt until the marginal cost of debt financing equals the marginal cost of equity financing (recall the discussion below equation 14). For a 1 percentage point tax cut, we find that the debt-to-capital ratio decreases by 0.3 percentage points, from the calibrated initial steady-state value of 56.7 to 56.4 %. The strength of this effect is determined by equity and bond risk premiums and the sensitivity of the bond risk premium to the debt-to-capital ratio, while being independent of the relocation channel. Our estimated effect coincides with the typical results in the empirical literature of about 0.3 percentage points; see e.g. Mooij and Ederveen (2008).

4.2 The role of relocation decisions

Together with the benchmark model results, Figures 2 and 3 show the corporate tax cut transmission in a model version in which firms are not able to relocate, and thus no firms move to Norway in response to the tax cut (red, dotted line). The intensive margin response is about 0.14% in the long-run. This shows that in the benchmark model foreign investment crowds out domestic investment through increased domestic competition more than the foreign investment boosts domestic investment through the increase in export demand. Hence these general equilibrium effects, competition and export spillovers, are on net negative for the intensive margin. The extensive margin effect is completely absent by construction, such that the total investment response is considerably smaller than in the benchmark model. As a consequence there is also no positive spillover on exports as a result of FDI. The effect on GDP is thus also relatively weak compared with the benchmark model, with an increase of 0.02 % compared with an increase of 0.17 % in the benchmark. By extension, the positive effects on employment, wages and consumption are generally smaller in the alternative model.

Thus this model comparison demonstrates the inadequacy of a model without relocation decisions for evaluating corporate tax reforms. Not only is such a model incapable of identifying the extensive margin response of investment. Quantitatively important spillover effects onto exports cannot be integrated into such a framework either. It is thus important to include relocation decisions in order to more realistically estimate the effects of corporate tax cuts on investment, GDP and employment.

4.3 The role of exports

In order to elucidate the link between exports and the investment response, we perform counterfactual simulations with alternative assumptions about the export-intensity of relocating firms. To do so, we vary the value of ξ_X, which determines how export-oriented those firms are. We keep the distribution of fixed mobility costs at its benchmark.

The results of the counterfactual computations are shown in Table 3. The first column shows the benchmark calibration. The second column shows the case when $\xi_X = 0$, in other words, when the relocating firms do not create any additional export demand. Instead, the new firms compete with incumbent firms into service the aggregate export demand Norway faces, which results in a rather weak response in terms of investment and output. The intensive margin investment is crowded out by the foreign investment and decreases by 0.2 % in the long-run. Also the extensive margin investment decreases. If we adjusted the sensitivity of location decisions as to match again the extensive margin with Mooij and Ederveen (2008), the intensive margin would be even more crowded-out.

In the third counterfactual shown in the last column of Table 3, we set $\xi_X = 4.32$, to match a liner projection elasticity estimate (see supplementary Figure S5 for details). In this case, the long-run investment response increases from 0.6 to 1.7%, with both the intensive and extensive margin increasing.

It is evident that the parameter governing the export demand sensitivity with respect to firm relocation (ξ_X) is key to the intensive as well as the extensive margin response of investment. Our benchmark calibration, informed by the FDI-export elasticity found in Popovici (2018), yields in total a relatively weak intensive margin response as the positive intensive margin response from the lower user cost of capital is offset by the general equilibrium intensive margin effects arising from more competition and export demand (which, as seen above, are net negative). However, assuming a much higher export sensitivity would turn the general equilibrium effect positive, implying a much stronger total intensive margin response.

Note that our model captures well the fact that the exported goods use imported goods as inputs, so that imports also increase markedly (O'Sullivan, 1993). Due to the appreciation of the exchange rate, imports increase more than exports in each of the counterfactuals. This weakens the positive effect on the trade balance of the host country. That higher export demand increases overall economic activity in the long run also depends on increased labour force participation. It is the rise in real wages and lower unemployment that leads to the increase in labour supply, a response which is consistent with the findings in Dagsvik et al. (2013).

Table 3: Counterfactual assumptions of export-orientation of relocated firms.

Variable	benchmark: $\xi_X = 2.86$	$\xi_X = 0$	$\xi_X = 4.32$
Elasticity of exports w.r.t FDI	0.20	−0.06	0.33
Investment, % change	0.62	0.10	1.67
Intensive margin	0.03	−0.20	0.49
Extensive margin	0.59	0.30	1.18
Mainland GDP, % change	0.17	0.02	0.48
Exports, % change	0.59	−0.09	1.94
Imports, % change	0.81	0.09	2.26
Trade balance (% of GDP)	0.12	−0.03	0.43

Numbers show the long-run change relative to the steady state following a 1 percentage point reduction in corporate tax. Export elasticity with respect to FDI is calculated as % change in exports divided by % change in extensive margin investment adjusted for the share of multinationals (0.2).

4.4 Decomposing the total investment response

The previous sections allow us to quantitatively decompose the total investment response into the three distinct channels through which corporate tax cuts affect investment: The user cost of capital, the relocation of firms and the FDI-export link.

First, in a model without relocation and thus with only the user cost of capital channel present (first row), investment only at the intensive margin increases, preventing the model from matching the empirical evidence on the responses at both margins of investment.

Second, the model with relocation but without the FDI-export link leads to a positive extensive margin response of investment (second row), in line with the empirical literature. However, the general equilibrium effect of crowding out domestic investment through competition depresses intensive margin investment considerably, implying counterfactually a strong decline in intensive margin investment.

Third, by including also the final channel, the FDI export link (third row), and calibrating it realistically to available empirical evidence, the crowding out of intensive margin investment is mitigated by higher export demand from which also incumbent firms profit. The higher aggregate demand also boosts the extensive margin to levels in line with Mooij and Ederveen (2008).

Table 4: Summary of the investment responses

	Intensive margin	Extensive margin	Total
No relocation	0.14	0.00	0.14
Relocation without FDI-export link	−0.20	0.30	0.10
Benchmark model (relocation with FDI-export link)	0.03	0.59	0.62

Long-run impacts (as % deviation) for a 1 pp cut in the corporate tax rate

4.5 The role of the tax depreciation rate

To isolate the role of the tax depreciation rate in the investment response, we perform a counterfactual to the benchmark corporate tax cut. In the counterfactual, we apply the corporate tax cut only to the profit taxation rate while holding the tax depreciation shield rate at its steady-state value. In analytical terms, this means that the tax burden of the firm in this counterfactual is given by $\tau_t \Pi_t - \tau_{ss} \delta_\tau K_t^\tau$. Figure 4 plots the result for the counterfactual simulation alongside the benchmark case.

As discussed in the previous section, we observe that a tax cut increases investment through the intensive margin and the firm relocation channel. This is because investment projects at the margin, which were deemed unprofitable pre-reform, now become worthwhile, as the tax cut lowers the pre-tax return that investors demand to break even. Similarly, lower taxation of profits makes it more attractive for foreign-located firms to produce in Norway, triggering relocation movements and boosting extensive margin investments. This channel is active both in the benchmark and in the counterfactual, as in both cases the tax rate on corporate profits is lowered.

However, in the case of the benchmark model, the tax cut also reduces the net present value of the depreciation shield, given by the product of the corporate tax rate and the depreciated capital. Hence, while the corporate tax cut lowers the required return component of the user cost of capital, it increases the user cost of capital component related to the depreciation shield, see section 2.4.1. This is also relevant for the relocation decisions of firms as, ceteris paribus, the loss in the depreciation shield deters firms from moving to Norway. As a consequence, if the depreciation shield effect is switched off as in the counterfactual (red, dotted line), the investment response is considerably larger, at both the intensive and the extensive margin.

Hence, model-based evaluations of corporate tax reforms that only include the required return channel will overestimate the effectiveness of corporate tax cuts in stimulating investments at the intensive margin, as the negative contribution by the depreciation channel is ignored.

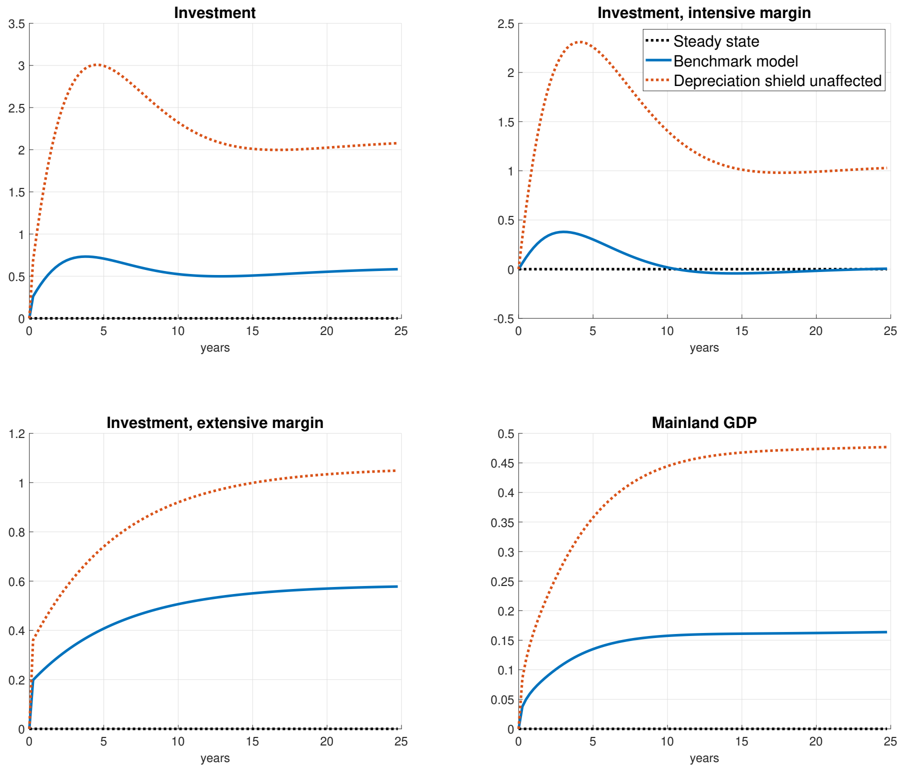

Figure 4: Effect of a corporate tax rate in the benchmark model compared to when the tax depreciation shield is unchanged. Per cent deviation from baseline

4.6 Self-financing effects

Fiscal authorities also care about the budgetary cost of a tax cut. Our model allows us to disentangle the various contributions to the self-financing of the tax cut from the main income and revenue items of the government budget. Table 5 shows how these items contribute to the funding of a one percentage point reduction in corporate profit tax. The three columns represent alternative model assumptions. Columns 1 and 2 show the benchmark and the model in which firms cannot relocate. Column 3 shows the benchmark model in which we additionally assume a reduced-form profit-shifting effect caused by the corporate tax cut.[35]

We base our profit-shifting effect on estimates as reported in SOU (2014) and NOU (2014), who assume an increase of 0.4 % in the tax base due to profit-shifting by multinational corporations in response to a 1 percentage point corporate tax cut.[36] The numbers in the table are percentages,

[35] Profit shifting is modelled as an increase in the corporate tax base which does not affect the economic behavior of the firm. Specifically, the corporate tax base is then written as $TB_t^{\Pi,M} = (\Pi_t^M - \delta_\tau P_t^I K_t^M - TD^{OIF})\gamma_t$ where factor γ_t depends linearly on the corporate tax rate such that the targeted profit-shifting elasticity is achieved.

[36] The estimate is obtained by multiplying the semi-elasticity of the profits of multinational corporations, which is 0.8 according to the recent study Heckemeyer and Overesch (2017), by the presumed share of multinational

with 100% corresponding to the size of the ex-ante fiscal impulse, i.e. the steady-state corporate tax base multiplied by 0.01. Income and expenditure components adjust to the new steady state and provide potential additional sources of financing, such that the residual amount that needs to be covered by oil fund withdrawals is less than 100% of the ex-ante fiscal impulse.[37]

In the benchmark case with firm relocation, there is large amount of self-financing coming from a number of tax bases (see the income components in Table 5). The largest self-financing contributions are attributable to the consumption tax base as well as the increase in various labour tax bases. The latter expand mostly for the reason of higher wages (as the larger capital stock renders labor more productive) and only modestly due to higher extensive-margin employment, see also Figure 3, while hours per employed are fixed in the long-run by construction. The corporate tax base also increases and contributes significantly to financing the tax cut. In the model without relocation (middle column) the tax bases increase generally less. The main reason is that in the absence of the additional export demand generated by the relocated firms, the effects on employment and wages are considerably smaller, and hence the labor and consumption tax bases will not increase by as much.

In the model that includes relocation and profit-shifting (far right column), the effects on tax bases are otherwise identical to the benchmark case, but there is an additional increase in the corporate tax base due to profit shifting.

Table 5 also shows the financing effects from the expenditure side. The effects on government purchases, investment, unemployment benefits, and debt service are relatively small.[38] However, the hike in wages following the corporate tax rate cut significantly increases the government wage bill. This in itself tends to make the tax cut more expensive than its ex-ante cost.

The last two rows of Table 5 summarize how the government budget is balanced by transfers with the oil fund. In the base line model with foreign investment, the self-financing degree is 124 %, meaning that government can save NOK 24 to the oil fund for every NOK 100 given in tax relief. The inclusion of the profit-shifting effect improves the self-financing rate to 134%. Self-financing excluding foreign investment amounts to 57%, meaning that the government has to draw on the oil fund to finance the tax cut.[39] Hence, modeling the extensive-margin response of investment to corporate tax cuts has important implications not only for the aggregate investment response but also for government budget effects. Taking into account the effects of attracting foreign investment as well as profit-shifting renders the corporate tax reform highly self-financing as opposed to in the model in which the economy is closed to foreign investment.

corporations in the tax base, 50%.

[37]See appendix H in the Annex for further discussion about the government budget constraint and the role of the oil fund in our model.

[38]These follow from small changes in prices, the interest rate and the unemployment level.

[39]The obtained self-financing degrees also depend on the assumptions on how government finances the deficit or spends the surplus. If we assume adjustments in transfers instead of oil-financing, the total self-financing rate in the absence of firm relocation becomes only 30%.

For comparison, the smaller models by Sørensen (2014) and Trabandt and Uhlig (2011) predict 38.5 % and 79 % total self-financing degree for capital taxes, respectively.[40] As a part of their analysis, the Norwegian expert group NOU (2014) applies the simple framework in Sørensen (2014) with parameters attuned to Norway, and find total self-financing degree of 27.8 %, most of which (14.9 %) are attributed to increase in labor income. Capital taxes contribute 6.4 %, savings 3.7 %, and consumption taxes 2.9 %. These numbers are low compared to both the benchmark model and the model without relocation. However, our model cannot be directly compared to Sørensen (2014), because the study excludes relocation decisions, social security taxes, dividend tax, and details of the public sector. His calculation also assumes that the tax decrease is financed by decreasing government consumption, while our tax cut is essentially unfinanced.

The Norwegian expert group on the tax reform proposal NOU (2014) further analyses the self-financing effect in the corporate tax base itself.[41] They split the self-financing portion of the corporate tax base (only) into parts that reflect the effects on intensive margin investment, extensive margin investment, the change in debt vs equity discrimination, and on profit-shifting. NOU (2014) refers to a tax cut from 27 % to 20 %, so our numbers reported in this paragraph correspond to long-run estimates from a separate simulation in which we also adjust (only) the corporate tax by 7 percentage points. The report estimates a self-financing contribution from an increase in investment at the intensive margin of 3-5 % while we obtain -1.7. %. The difference can be attributed to the crowding-out of domestic investment by foreign investment. According to NOU (2014) the extensive margin investment contributes 11-15 %, while our result is 12.4 %. For the debt vs equity discrimination channel, they estimate 3 % of self-financing while our result is 1.4 %. Our smaller effect is partly because the equity premium increases with decreasing corporate tax rate. Both we and the report find an 8 % contribution to self-financing from profit-shifting, as we use the same calibration strategy. Finally, note that when we assume that other countries follow suit and firms have neither an incentive to shift profit or location, the self-financing effects from the extensive margin investment and profit-shifting amount to zero. In this case, there is no crowding-out of intensive margin investment, so we obtain a positive self-financing contribution of 0.5 %, which is still smaller than the estimate reported by NOU (2014). The self-financing contribution from the shift from debt to equity financing, is 1.3 % and thus roughly the same as in the benchmark model.

Overall, our estimates on the self-financing contribution through the corporate tax base channel is somewhat lower than estimated by NOU (2014). However, the expansion of other tax bases caused by general equilibrium effects contribute strongly to self-financing, see the discussion

[40] In these models, business taxation is proxied through a capital tax (only), which applies to the capital stock of the firm. Sørensen (2014) states that a rise in the effective capital tax rate could be implemented by a rise in corporate income tax or broadening of the respective tax base.

[41] The expert group based their analysis on the estimates provided in Mooij and Ederveen (2008) and Heckemeyer and Overesch (2017).

Table 5: Financing contributions from each item in the government budget

	Benchmark	No relocation	Profit shifting
Ex-ante fiscal impulse	100	100	100
Income components	198	69	209
Corporate profit tax	16	2	27
Consumption tax	52	20	52
Ordinary income tax	74	38	74
of which labor income	56	9	56
of which interest income	2	1	2
of which dividend income	15	28	15
Labor surtax	17	3	17
Household social security contributions	4	1	4
Firm social security contributions	36	6	36
Expenditure components	-75	-12	-75
Government purchases and investment	-5	-1	-5
Government employment	-68	-11	-68
Unemployment benefits	0	0	0
Government debt servicing	-2	0	-2
Oil fund withdrawals	-24	43	-35
Self-financing rate	124	57	135

Following Trabandt and Uhlig (2011), the financing contribution for budget items Z other than corporate tax revenue is calculated as $\pm\Delta Z/(TB_{SS}^{OIF}\Delta\tau_{OIF})$, where a plus sign applies to expenditure items and a minus sign applies to tax items. The self-financing contribution from the corporate tax base is calculated as $1+\Delta T/(TB_{SS}^{OIF}\Delta\tau_{OIF})$, where TB_{SS}^{OIF} is the corporate tax base (taxable income) and $\Delta\tau_{OIF}$ is the change in the corporate profit tax rate (1 pp). Benchmark = model with foreign investment and without profit shifting. No relocation = model without foreign investment and without profit shifting. Profit shifting = model with foreign investment and with profit shifting.

earlier, leading to an overall high self-financing degree of the corporate tax cut.

Figure 5a shows Laffer curves for the corporate tax rate. We follow Trabandt and Uhlig (2011) in that the Laffer curve shows total tax revenue and so does not include the effects from the expenditure side of the government budget. In the absence of firm relocation (dashed red line in Figure 5a), we obtain a Laffer curve with the traditional hump-shape of the literature. In contrast, in the benchmark model with foreign investment (solid blue line in Figure 5a), the Laffer curve is initially downward sloping. The hump-shape is now absent because tax revenue is maximized at a negative corporate tax rate of -18 %. Hence, we replicate the traditional hump-shaped Laffer curve only when assuming away firm mobility. This can alternatively be interpreted as a situation in which the corporate tax rate is adjusted simultaneously and equally in all countries so that firms have no tax-based incentives to relocate.

The Laffer curve only measures tax revenue, so it does not take into account the fact that the

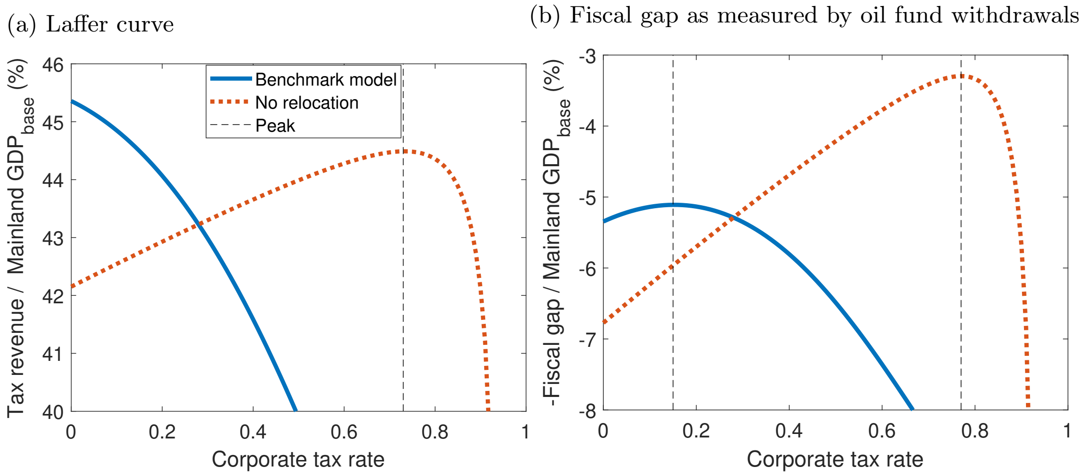

Figure 5: Government revenue-maximizing tax rate. The graphs shown are normalized such that the level at 28% corporate tax rate corresponds to 100.

government expenditures increase. The full effect on government finances is better captured by figure 5b, which shows how the budget balancing oil-fund withdrawals, i.e. the fiscal gap, depend on the corporate tax rate. By looking at the balancing item, we can identify the corporate tax rate which requires the least amount of balancing (as measured by the negative of the fiscal gap). In the benchmark model, the fiscal gap initially decreases when we move towards the left from the initial 28% tax rate, and the fiscal gap is minimized at a tax rate of 15 %. This is in contrast to the model without firm mobility, where the fiscal gap increases with a decreasing corporate tax rate.

Our analysis thus shows that the shape of the Laffer curve hinges decisively on assumptions about international developments in corporate profit taxation. Only when we assume that other countries follow suit in lowering corporate tax rates can we confirm the finding of a hump-shaped Laffer curve peaking at levels substantially above 50%. However, when the reform is undertaken as a unilateral national action, the Laffer curve peak is obtained at much lower levels of the corporate tax rate. If policy makers want to avoid a race to the bottom for corporate taxes, these results point towards the importance of international coordination in setting the tax levels.

5 Application: Norway's tax reform of 2014-2019

In this section, we evaluate the Norwegian corporate tax reform using the framework developed in the preceding sections. We first provide an overview of the reform, which encompassed not only changes in the corporate tax rate but also in the way personal income is taxed. Then we evaluate the different components and overall effects of the tax reform by observing how the tax changes affect the economy in the mainland Norway.

Overview of the Norwegian tax reform

Prior to the 2014–2019 tax reform, the ordinary income tax rate for both firms and households in Norway was 28 percent, the level set in the 1992 tax reform.[42] Personal income tax had a progressive structure achieved through a two-step surtax on employment income. Between 1992 and 2006, had a substantial incentive to shift labor income into capital income Alstadsæter and Fjærli (2009). The 2006 tax reform reduced the labor surtax from 19.5 % to 9 % and introduced the shareholder model for personal ownership, according to which the equity premium on capital gains and dividends is taxable as ordinary income while the risk-free return is tax-exempt.[43] This special tax system, referred to as the ASE model (allowance for shareholder equity), has the advantage that investments and optimal debt ratios are neutral with respect to the level of the dividend tax.[44] Note that the ASE system is different from the ACE tax system implemented in some countries in which the cost of equity is deductible at corporate level.

In anticipation of the broader tax reform, the corporate tax rate was reduced to 27% from beginning of 2014. The following year, after a recommendation by a government-appointed expert committee (NOU, 2014), the Solberg I government decided to decrease the corporate tax on profits gradually to 22% over the period 2016-2019 (Finansdepartementet, 2015). To avoid the re-emergence of incentives for profit shifting between labor and dividend income, personal income tax was reduced symmetrically, while both the tax on dividends and the labor surtax were increased. Furthermore, tax rate adjustments were made to equalize the total marginal tax rates for the dividend income and labor income to neutralize related profit-shifting incentives. The financing of the tax cuts included various other tax adjustments, the most important being an increase in the labor surtax, neutralization of the tax effect on petroleum and hydropower industries,[45] a new tax on the financial industry, and the elimination of some deductions.

In summary, the main changes in taxation that we will consider are:

- Corporate tax
  - A decrease in the statutory tax rate from 28 % to 22 %, which corresponds to a

[42] Before the 1992 tax reform, the corporate tax rate was 50.8% and the top marginal rate on employment income was 57.8%.

[43] See Alstadsæter and Fjærli (2009) for a detailed discussion of the Norwegian dividend tax system before and after the reform.

[44] The ASE tax system is modelled in detail in the NORA model. As a consequence, dividend taxes are neutral in the model, so that financing of government spending by means of lump-sum taxes or by dividend taxes amounts to the same.

[45] Taxes on immobile natural resources were adjusted gradually over the period 2016–2019 from 51 % for petroleum and 31 % for hydropower to 56 and 37 percent, respectively.

decrease in the effective corporate profit tax rate[46] from 28% to 22.5%;

- Personal income tax
  - A decrease in the statutory ordinary personal income tax rate from 28 % to 22 % which corresponds to a decrease in the effective ordinary income tax rate from 23.8 % to 19.3 %;
  - The introduction of a scale-up factor for dividend tax (1.44 in 2019) consistent with an increase in dividend tax from 28 to 31.68 %;[47]
  - The tax surcharges in the (now four) income brackets were increased gradually from [0 %, 0 %, 9 %, 12 %] in 2015 to [1.9 %, 4.2 %, 13.2 %, 16.2 %] in 2019, which corresponds to a 2.3 pp increase in the effective surtax tax rate.
  - A 0.4 pp increase in the effective household's social security contribution rate.

In the following, we discuss the effects of different components of the 2014-2019 tax reform on activity in mainland Norway. We define the 2014-2019 tax reform as a combination of the tax changes listed above. As the main focus of this article is on corporate taxes, we refer the reader interested in the theory behind the pass-through of the personal income taxation in NORA model to Aursland et al. (2019). Thanks to the high self-financing degree of the corporate tax cuts, the overall reform proves to lead to a budget surplus. We assume that this surplus is absorbed by less withdrawals from the oil fund (GPFG), which households do not internalize as their own wealth. Consequently there are no additional income effects on households beyond the aforementioned tax changes. It is important to note that when we isolate the effect of the tax changes in Norway, we assume the international tax rates to remain unchanged. Since there actually was a coincident decline in foreign tax rates, the assessed impact should not be seen as a forecast for the Norwegian economy but rather as a quantification of the isolated effects, which could be useful for cost-benefit analysis.

Effect on investment and activity in mainland Norway

At first it is important to point out that according to our analysis, the reduction in the corporate tax rate dominates the reform, while the other tax adjustments alter the picture in a very modest way. This can be seen in Figure 6, which shows the response of investment and output (as % increase relative to the initial steady state) to the broader reform and to a stand-alone reduction in corporate tax from 28 % to 22 %. In the long-run, investment increases by 3.3 % in response to the stand-alone corporate tax cut and 3.5 % in response to the broader reform.

[46] Not to be confused with the EMTR or EATR, the effective tax rate is defined as taxes paid divided by taxable income. Effective tax rates are available in Statistics Norway's Survey of Tax Assessment, Table 08564.

[47] We define the dividend tax rate as the ordinary income tax rate multiplied by the scale up factor.

The corresponding increases in intensive margin investment are 0.2 and 0.1%, and in extensive margin investment 3.2 and 3.3 %, respectively. The long-run effects on mainland output are 0.9 and 1.1 %, respectively.

Hence, the effect of the broader reform is almost equivalent to the effect of the reduction in corporate profit tax alone. On the one hand, this can be attributed to the neutrality of the dividend tax in the ASE tax system (see appendix F) and to the fact that the increase in dividend tax has only a small negative effect on income. On the other hand, there is little change in labor taxation at aggregate level, as ordinary income tax on labor falls while labor surtax increases. Overall, there is a small net decrease in labor taxes, which increases labor force participation (not shown in the figure), employment, and wages. This leads to a positive income effect that more than offsets the negative income effect due to the increased dividend taxation. Moreover, the higher employment increases the marginal productivity of capital and further stimulates intensive margin investment; see more details in supplement B.

Table 6 summarizes the effects of the 2014-2019 tax reform by reporting the changes in selected variables five years after the first year of the reform (beginning of 2019), after ten years (beginning of 2024), or at the long-run steady state, which is realized after around 25 years. As well as the variables contained in the figures, the table shows that the user cost of capital decreases by 0.1 %. The firms debt-to-capital ratio decreases by 0.3 percentage points, which contributes to an increasing tax base as discussed in section 4.1. Changes in the labor market are realized gradually. Within the first five years, labor force participation increases by 0.25 % and in the long-run by 0.36 %. Employment eventually increases by 0.7 % and the unemployment rate decreases by -0.2 percentage points. Pre-tax wages increase more gradually and eventually by 2.5 %. Thanks to the increase in the wage bill and in employment, the household consumption increases gradually, and finally by 3.3 %. Interest rate and inflation react very little, and are mostly driven by the real exchange rate, which appreciates by almost 4 % in the long-term.[48] The last row in Table 6 shows that the fiscal impulse (defined as the change in the government budget balance) changes its sign over time and that after 10 years the tax reform reduces the size of the deficit by 0.3 % of GDP.

The forth column in Table 6 shows the long-run response if the tax reduction in Norway causes foreign countries to cut their taxes, so that firms have no incentive to relocate. In this case, investment increases only through the partial equilibrium intensive margin channel. The overall increase in investment and output is reduced to 0.8 %. Increases in consumption, labor force participation, employment, and wages are also smaller.

Note that if foreign countries reduced their taxes and Norway did not, there would be a negative impact on the Norwegian economy. To this end, the far right column in Table 6 illustrates

[48]The assumed Taylor rule depends on the real exchange rate, see Aursland et al. (2019) for details.

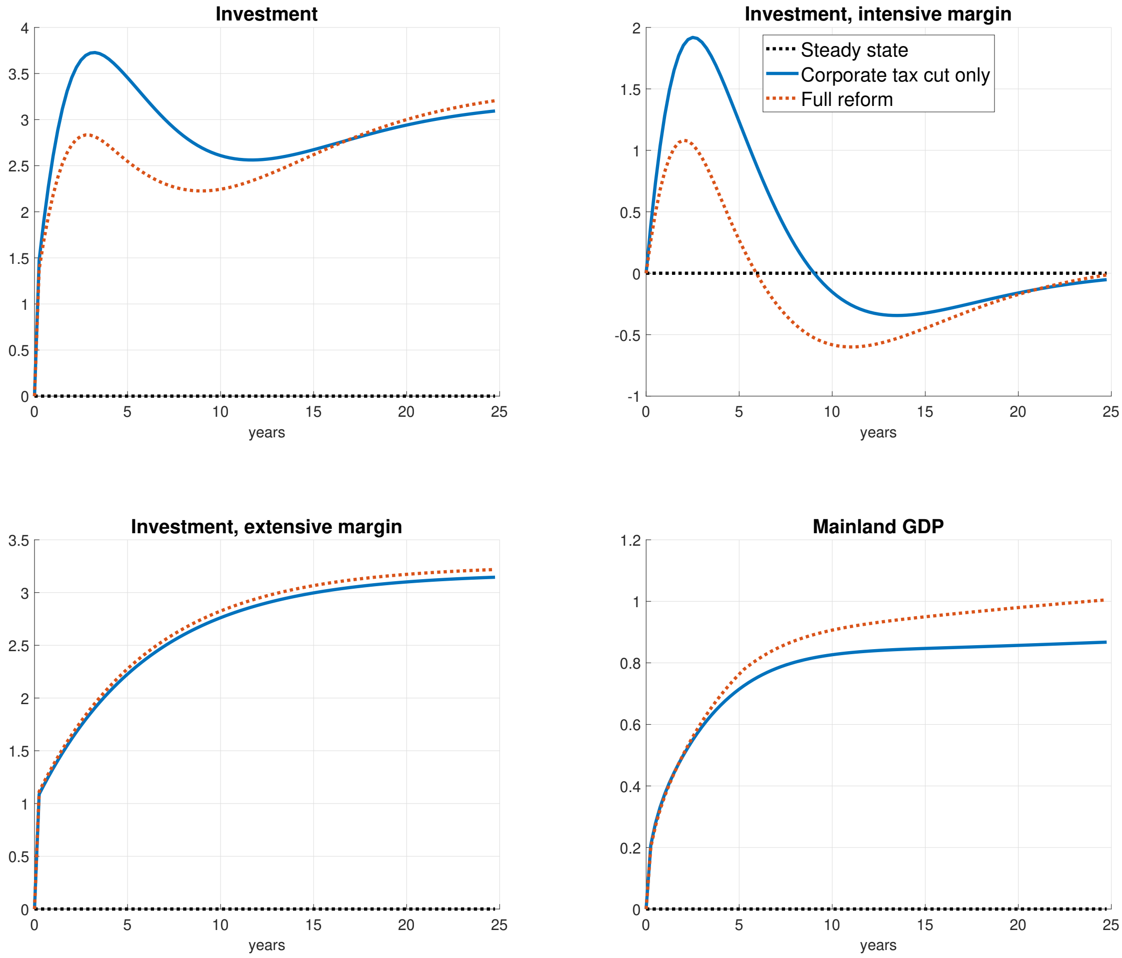

Figure 6: Response of investment and GDP to the Norwegian tax reform. Per cent deviation from baseline. Time period 0 corresponds to 2013Q4.

the effect on Norwegian mainland economy of a one percentage point reduction in the foreign corporate tax rates. The mainland output, investments, and consumption decline, and the employment decreases. Also the government finances are impacted negatively. In this sense, the Norwegian tax reform can be seen as partly countering the fleeing of the tax bases through international competition and partly correcting incentives in domestic taxation.

Table 6: Effects of the 2014-2019 tax reform. Change in percentage points (unless stated otherwise) relative to a no-reform reference.

Variable	5 years	10 years	Long-run	No relocation	Foreign tax cut
Mainland GDP, % change	0.75	0.90	1.09	0.27	−0.15
Investment, % change	2.59	2.24	3.48	0.82	−0.48
Intensive margin	0.35	−0.57	0.22	0.82	0.10
Extensive margin	2.24	2.81	3.26	0.00	−0.58
User cost of capital, % change	−0.08	−0.05	−0.07	−0.18	−0.03
Debt-to-capital ratio	−0.33	−0.30	−0.31	−0.35	−0.01
Consumption, % change	1.71	2.34	3.28	1.33	−0.35
Labor force participation	0.25	0.31	0.36	0.15	−0.04
Employment, % change	0.53	0.60	0.66	0.24	−0.08
Unemployment rate	−0.18	−0.17	−0.15	−0.02	0.02
Pre-tax wages, % change	1.02	1.72	2.52	0.31	−0.40
Interest rate (pp, annual.)	−0.15	0.07	0.00	−0.13	−0.02
Inflation rate (pp, annual.)	−0.01	0.16	0.11	0.01	−0.02
Trade balance (% of GDP)	0.33	0.60	0.65	−0.26	−0.17
Real exchange rate, % change	−1.84	−2.57	−3.50	−0.35	0.56
Fiscal impulse (% of GDP change)	−0.12	0.02	−0.26	0.20	0.08

The interest and inflation rates are given in annualized terms. The trade balance is expressed as a percentage of mainland GDP. A negative change in the real exchange rate corresponds to an appreciation of the Norwegian krone. The fiscal impulse is expressed as % of mainland GDP and corresponds to the amount withdrawn from the oil fund that balances the budget. The foreign tax cut scenario shows the impact from a one percentage point reduction in the foreign corporate tax rates. The time horizon is calculated from the beginning of the tax reform, so the 5-year column refers to the beginning of year 2019, while 10 years refers to the beginning of 2024.

Financing the 2014-2019 tax reform

In analogy with 4.6, we can calculate a degree of self-financing for the reform package.[49] The self-financing rate is given by a ratio of two terms, where the numerator is the ex-post change in budget surplus caused by the reform package minus its ex-ante change and the denominator is the ex-ante change in budget surplus. The self-financing rate of the full reform amounts to 135 %. In other words, for every NOK 100 spent on tax cuts, the government eventually reduces government spending by NOK 35. The reform not only finances itself, it generates excess tax revenue. As discussed previously, this high degree of self-financing only occurs provided that other countries do not simultaneously lower their corporate tax rates. If we assume that they act in such a way that firms find it neither beneficial to move to Norway nor to leave it (which means profit-shifting would also have no effect), the self-financing rate shrinks to 73 %.[50] We refrain from discussing the effects of the full reform on the government budget in more detail, as the effects are quantitatively very similar to those analyzed above in section 4.6. The interested reader is instead referred to our supplementary table S1, which provides detailed tabulation of financing effects.

[49] This is possible as long as the ex-ante change in tax revenue is different from zero

[50] Note that financing the deficit with transfers or taxes instead of withdrawals from the oil fund as assumed here would have a negative self-financing effect.

6 Conclusion

In this paper, we have studied how lower corporate tax rates impact investment by extending a DSGE model used for fiscal policy analysis in Norway. Our extended model captures three distinct channels for how a lowering of the corporate income tax increases investment. First, it lowers the user cost of capital, so domestic firms increase investment. Second, it increases the incentive to relocate through the extensive margin, so foreign firms relocate and invest in the country. Third, the inflow of FDI increase exports which spills over to domestic firms who then increase their investment further. We referred to the latter channel as the FDI-export link.

Our contribution to the literature has been to analyse the importance of both location shifts and the FDI-export link. We found that a one percentage point reduction in the corporate tax rate increases investment by 0.6 %, most of which can be attributed to the FDI-export link.

From the government's perspective, the relocation channel as well as the FDI-export spillover channel makes corporate tax cuts self-financed and the Laffer curve downward-sloping. With firm relocation and the FDI-export link, the self-financing rate is 124 %. This means that the government can save an additional NOK 24 for every NOK 100 given as tax relief. However, without these channels, the self-financing rate drops to 57 %. These results have important implications for the interpretation of corporate tax reductions in small open economies. Even though it may be fiscally beneficial for a small open economy to cut corporate taxes, our results show that it will still be costly if other countries follow suit, since international firms will then have no incentive to relocate. Our findings therefore demonstrate the fiscal incentives underlying international tax competition.

We used the extended model to analyze the tax reform in Norway from 2014 to 2019, where, inter alia, the corporate tax rate was gradually reduced from 28 % in 2013 to 22 % in 2019. When first considering unchanged foreign tax rates, we found that the reform, is isolation, increases investment by about 3.5 % and mainland GDP by about 1.1 %, in the long-run. The self-financing rate is estimated to be around 129 % when firm relocation and profit shifting is included. However, when firm relocation is excluded, on the assumption that many other countries have made corresponding reductions in their corporate income tax, we found that the positive long-run impact of the tax reform on mainland GDP is reduced to well below 1 %. Moreover, when both firm relocation and profit shifting are excluded, the self-financing rate drops from 129 % to 73 %.

There are several aspects of how corporate taxes impact economic aggregates that need further study. In this paper, we have not analyzed welfare effects or the impact on inequality. To examine welfare effects, a model that also captures the value of leisure and the disutility of work should be used, possibly also including leisure externalities; see e.g. Pintea (2010). The methods reviewed by Thoresen et al. (2016) could be used to study the distributional impact. We leave this for future research.

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(a) Varying r (annualized) (b) Varying δ_τ (annualized) (c) Varying τ_{ss}

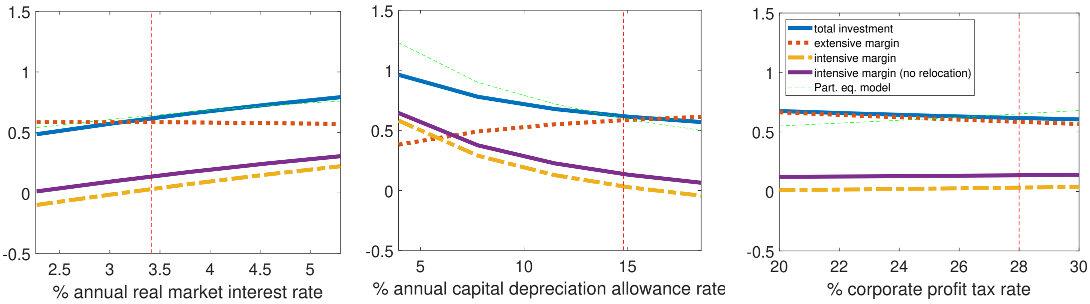

Figure S1: Long-run investment response to a 1 pp corporate tax cut. Per cent deviation from baseline

Appendices

A Sensitivity analysis

Sensitivity with respect to interest, tax depreciation and corporate tax rates

We have identified three determinants of the intensive margin response of investment to a corporate tax cut in the analytical section 2.4.2: the (steady-state) market interest rate, the tax depreciation rate and the pre-reform level of the corporate tax rate. In figure S1 we plot the long-run increase in investment (as % increase relative to the initial steady state) following a 1 pp corporate tax cut against different values of these three determinants. In the figure we show not only the intensive margin response as predicted by the analytical, partial equilibrium model, but also the simulated, general-equilibrium intensive and extensive margin response of investment. Figure S1a plots the long-run investment response as a function of the steady-state market interest rate (which we vary by choosing the risk-free rate in our steady-state calibration accordingly). Figure S1b plots this response as a function of the tax depreciation rate and figure S1c as a function of the initial level of the corporate tax rate. The vertical line in each graph represents the steady-state base calibration of the model.

Focusing first on the intensive margin (yellow dashed line with relocation and purple line without relocation) and the derived partial equilibrium prediction for the intensive margin from section 2.4.2 (green densely dashed line) we observe that the analytical results are qualitatively confirmed by the full simulation. The effect on intensive-margin investment is larger in a high interest rate environment, for lower values of the capital depreciation allowance rate and for higher pre-reform tax rates. In terms of the size of the response, the analytical, partial-equilibrium predictions differ somewhat from the simulated intensive-margin responses, implying that general equilibrium effects matter. These are due to spillover effects from firm location to export demand and the corresponding positive effects on domestic production.

While the level of the market interest rate does not influence the strength of the extensive margin response in any significant way (red dotted line), more generous tax depreciation rates and a lower pre-reform tax level tend to attract more firms for a given tax rate cut. The sensitivity analysis suggests that, overall, each of the three determinants has a bearing on the aggregate investment response. The investment response to the market interest rate is significantly lower at today's interest rate levels than to the rates of 5 pp and more that predominated prior to 2000. Tax cuts tend to have a stronger effect on investment when capital depreciation allowances are less generous. Finally, the investment response is also stronger at lower levels of the corporate tax rate, implying that large tax cuts have more pronounced effects than simple extrapolation of a smaller tax cut would suggest.

Thus, while the model predicts that corporate tax cuts generally increase investment, their effectiveness may vary across countries depending on the generosity of capital depreciation allowance rates and initial corporate tax rate levels, and at different times with differing market interest rate levels. Our analysis suggests that taking each of the three determinants into account is important for reaching reliable estimates of corporate tax elasticities.

B Supplementary graphs and tables illustrating the 2014-2019 tax reform

B.1 Effects from changes in capital income and labor taxation

This supplement includes some figures that were excluded from the main article for the sake of brevity.

Figure S2 shows the response of the main macroeconomic variables to the reform. Since the reduction in corporate tax is the main driver of the results, the responses are qualitatively similar to the transmission channels already discussed in section 4.1. However, since the corporate tax rate cut in this section is six times larger than the 1 pp tax cut considered before, the responses across all variables roughly scale by a factor of six. The main difference is that the reform has an additional effect of a net decrease in labor taxes. Hence, the response of employment to the reform is somewhat stronger than it is to the corporate tax cut alone.

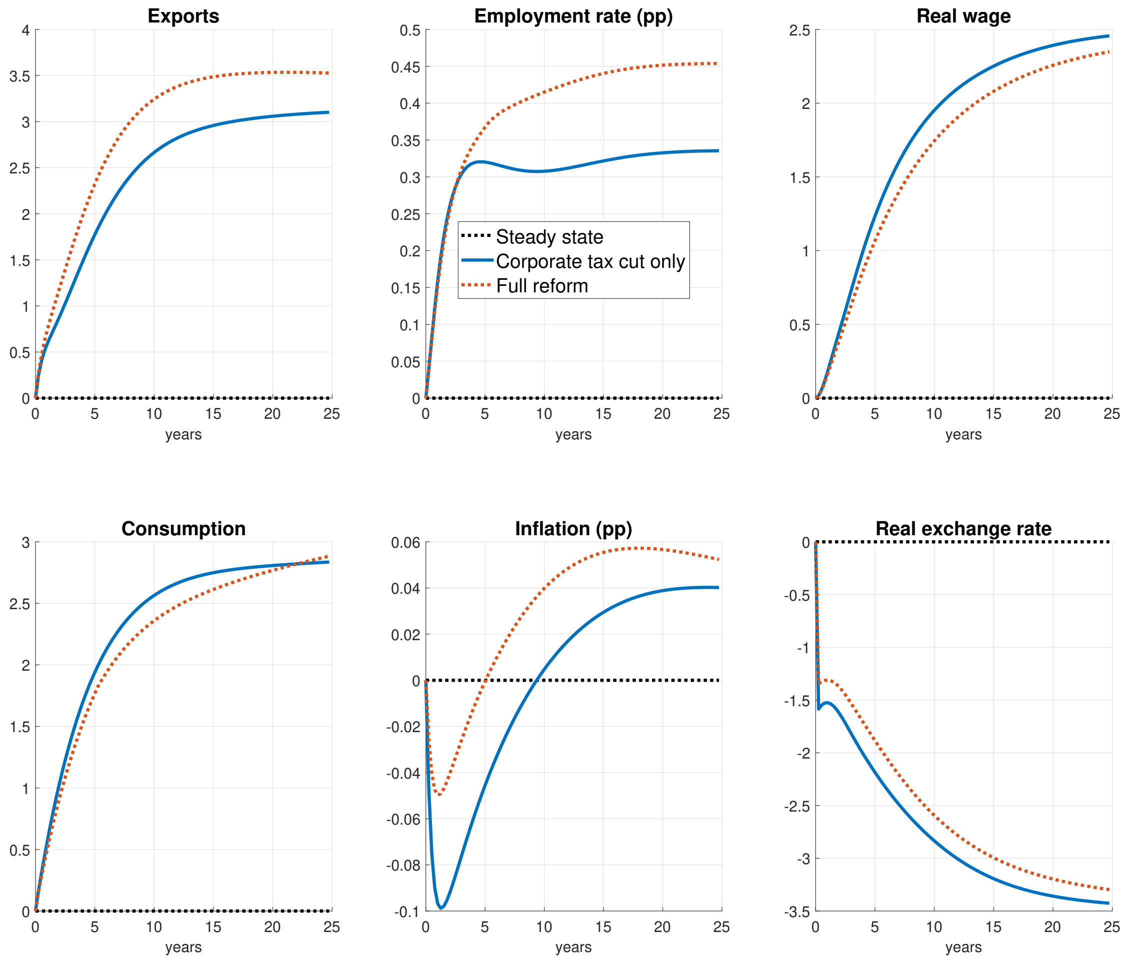

Figure S2: Response of further macroeconomic variables to the Norwegian tax reform. Per cent deviation from baseline unless stated otherwise. Time period 0 corresponds to 2013Q4.

The 2014-2019 tax reform adjusted personal income taxation in three ways. First, the ordinary income tax rate, which pertains to labor, interest, and dividend income, was cut by an amount corresponding to a 4.5 percentage point decrease in the effective tax rate. Second, a new scale-up factor of 1.44 for dividends was introduced such that when the shareholder receives 100 kroner in taxable dividend, the dividend tax is calculated on the basis of NOK 144 of dividend. Labor surtaxes were adjusted such that the effective labor surtax increased by 2.3 pp. We can separate the effect of the dividend tax adjustment from these other adjustments, which mainly pertain to labor income. Viewed in isolation, dividend tax increased from 28 to 31.68%.

Figures S3 and S4 show the response of key variables to the two fiscal shocks: dividend tax adjustment and labor tax adjustment. The labor tax adjustment is expansionary, as it leads to a net decrease in labor taxes which is financed by withdrawals from the oil fund. The lower labor tax leads to higher labor force participation and employment. There is an increase in investment due both to an income effect and to an increase in marginal productivity of capital attributable to higher employment. In contrast, the dividend tax adjustment is mildly contractionary. In the ASE tax system of NORA, the increase in dividend tax is equivalent to a lump-sum tax hike. This negative income effect causes consumption and investment to decline. If the dividend tax proceeds were redistributed to households in the form of lump-sum transfers, the dividend tax would be exactly neutral, implying that all responses shown here would be zero.

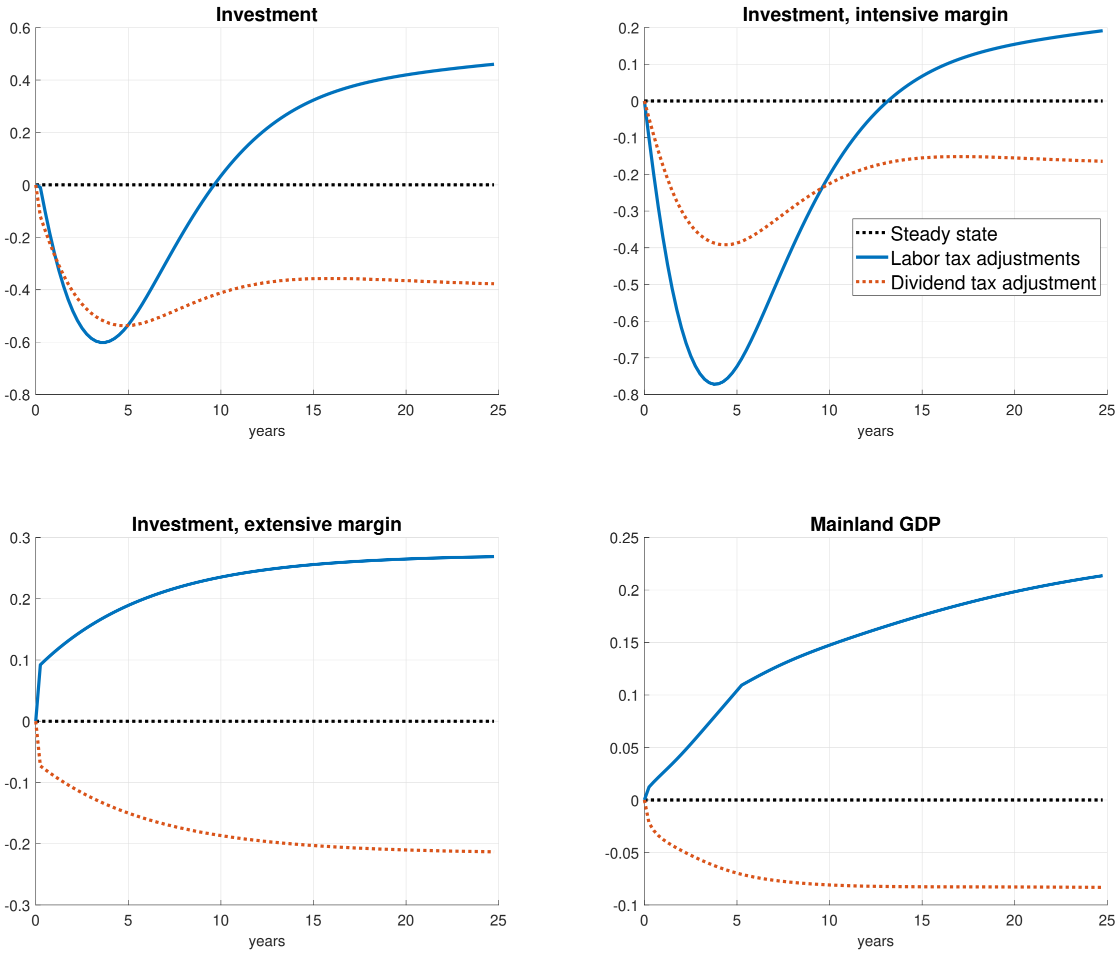

Figure S3: Response of investment and GDP to the Norwegian tax reform. Time period 0 corresponds to 2013Q4.

B.2 Self-financing in the 2014-2019 reform

Table S1 shows the self-financing contributions from different tax bases. The first column shows the result for the corporate tax cut only and the second column shows the result for the full reform.

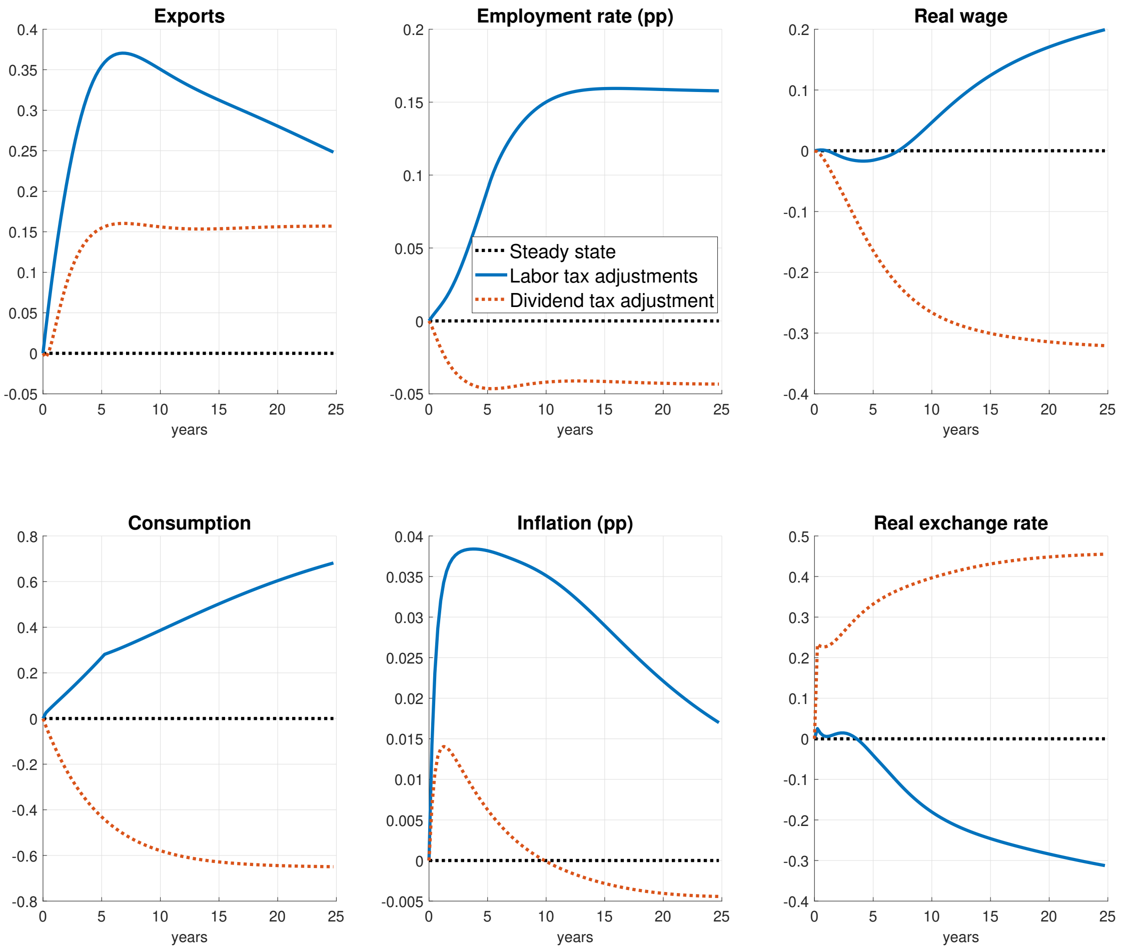

Figure S4: Response of further macroeconomic variables to the Norwegian tax reform. Time period 0 corresponds to 2013Q4.

They both include the effect of profit-shifting, which contributes about 8 percentage points to the self-financing of the reform. The third column shows the self-financing contributions when no relocations are assumed to take place, corresponding to a scenario in which tax rates are reduced internationally by the same amounts as in Norway so that firms have no tax incentive for moving.

Table S1: Financing contributions from each item in the government budget for the 2014-2019 tax reform

	Corporate tax only	2014-2019 tax reform	No relocation
Income components	202	191	74
Corporate profit tax	22	20	2
Consumption tax	51	49	20
Ordinary income tax	73	64	42
of which labor income	55	41	7
of which interest income	2	7	6
of which dividend income	15	16	30
Labor surtax	17	21	4
Household social security contributions	4	4	1
Firm social security contributions	35	32	5
Expenditure components	-73	-56	-0
Government purchases and investment	-5	-4	-0
Government employment	-66	-58	-7
Unemployment benefits	0	0	0
Government debt servicing	-2	6	7
Oil fund withdrawals	-29	-35	27
Self-financing rate	129	135	73

Consistent with the table presented in the main text, the financing contribution for budget items Z that are not impacted ex-ante is calculated as $\pm\Delta Z/\sum_X(TB^X_{SS}\Delta\tau^X)$, where plus sign applies to expenditure items and minus sign applies to tax items and where the sum over X includes corporate tax, personal ordinary income tax excluding dividends, social security contributions of households, labor surtax, and dividend tax. The self-financing contribution from those tax bases that are impacted ex-ante is calculated as $\Delta TB^Z\tau^Z_{end}/\sum_X(TB^X_{SS}\Delta\tau^X)$, where τ^Z_{end} is the final tax rate for the tax Z. Profit-shifting is assumed to contribute to self-financing from corporate profit tax for the first two columns only.

C Derivation of firm-specific first-order conditions

In line with Aursland et al. (2020), we assume the following functional forms for adjustment costs:

$$AC_t(i) = \frac{\chi}{2}\left(\frac{\frac{P^Y_t(i)}{P^Y_{t-1}(i)}\pi_t}{\left(\frac{P^Y_{t-1}}{P^Y_{t-2}}\pi_{t-1}\right)^{\omega_{Ind}}\pi_{ss}^{1-\omega_{Ind}}} - 1\right)^2 Y_t P^Y_t,$$

where $AC_t(i)$ denotes real price adjustment cost for firm i, χ is a parameter determining the magnitude of adjustment costs, and ω_{Ind} is a parameter determining the degree of price indexation.[51]

[51] $\frac{P^Y_t(i)}{P^Y_{t-1}(i)}\pi_t$ is equivalent to $\frac{P^{Nom}_t(i)}{P^{Nom}_{t-1}(i)}$, implying that adjustment cost operate on the nominal price.

The firm incurs costs to adjusting the level of investment

$$AC_t^{Inv}(i) = \left(\frac{\chi_{Inv}}{2} \left(\frac{Inv_t(i)}{Inv_{t-1}(i)} - 1 \right)^2 \right) Inv_t,$$

where χ_{Inv} is a parameter determining the magnitude of investment adjustment costs. Additionally, firms face costs when adjusting the level of new borrowing. Preserving the symmetry with investment adjustment costs we assume borrowing adjustment costs to be given by

$$AC_t^{BN}(i) := \left(\frac{\chi_{BN}}{2} \left(\frac{BN_t(i)}{BN_{t-1}(i)} - 1 \right)^2 \right) BN_t.$$

We express the problem of firm i (without using the index i unless necessary) from the perspective of period zero by the Lagrangian

$$\begin{aligned}
\mathcal{L} = E_0 \sum_{t=1}^{\infty} \Delta_t^{DIV} \Bigg\{ & \Big[P_t^Y Y_t - (1+\tau_t^{SSF}) W_t N_t - (R_{t-1}^L RP_{t-1}^B - 1) \frac{B_{t-1}}{\pi_t} \\
& -(AC_t + AC_t^{Inv} + AC_t^{BN}) \Big] (1-\tau_t) + \tau_t \delta_\tau K_t^\tau + \tau_t TD - \left[P_t^I Inv_t - BN_t \right] + \\
& + \lambda_t^K \left[Inv_t + (1-\delta) K_t - K_{t+1} \right] \\
& + \lambda_t^{K^\tau} \left[\frac{P_t^I Inv_t}{\pi_{t+1}} + \frac{(1-\delta_\tau) K_t^\tau}{\pi_{t+1}} - K_{t+1}^\tau \right] \\
& + \lambda_t^B \left[BN_t + B_{t-1}/\pi_t - B_t \right] \\
& + \lambda_t^Y \left[Y_t(i) - \left(\frac{P_t^Y(i)}{P_t^Y} \right)^{-\epsilon_M} Y_t \right] \Bigg\},
\end{aligned}$$

1. $\frac{\partial L}{\partial N_t^M} = 0$ yields

$$\begin{aligned}
0 &= (1+\tau_t^{SSF})(-W_t)(1-\tau_t) + \lambda_t^Y (1-\alpha_M) \frac{Y_t}{N_t} \\
\Leftrightarrow (1+\tau_t^{SSF}) W_t &= \lambda_t^Y (1-\alpha_M) \frac{Y_t(i)}{(1-\tau_t) N_t}
\end{aligned}$$

2. $\frac{\partial \mathcal{L}}{\partial P_t^Y} = 0$ yields

$$0 = \Delta_t^{DIV} \Bigg((1-\tau_t)(1-\epsilon_M) \left(\frac{P_t^Y(i)}{P_t^Y} \right)^{-\epsilon_M} Y_t + \lambda_t^Y \left[-\frac{-\epsilon_M}{P_t^Y(i)} Y_t(i) \right]$$

$$-(1-\tau_t)\chi_M P_t^Y Y_t(i) \left[\frac{\frac{P_t^Y(i)}{P_{t-1}^Y(i)} \pi_t}{\left(\frac{P_{t-1}^Y}{P_{t-2}} \pi_{t-1} \right)^{\omega_{Ind}} \pi_{ss}^{1-\omega_{Ind}}} - 1 \right] \left[\frac{\pi_t}{\left(\frac{P_{t-1}^Y}{P_{t-2}} \pi_{t-1} \right)^{\omega_{Ind}} \pi_{ss}^{1-\omega_{Ind}} P_{t-1}^Y(i)} \right] \Bigg)$$

$$-\Delta_{t+1}^{DIV} (1-\tau_{t+1}) \chi_M P_{t+1}^Y Y_{t+1}(i) \left[\frac{\frac{P_{t+1}^Y(i)}{P_t^Y(i)} \pi_{t+1}}{\left(\frac{P_t^Y}{P_{t-1}^Y} \pi_t \right)^{\omega_{Ind}} \pi_{ss}^{1-\omega_{Ind}}} - 1 \right] \left[\frac{\pi_{t+1} P_{t+1}^Y(i)}{\left(\frac{P_t^Y}{P_{t-1}^Y} \pi_t \right)^{\omega_{Ind}} \pi_{ss}^{1-\omega_{Ind}} (-1)(P_t^Y(i))^2} \right]$$

For notational ease we introduce

$$DAC_t = \chi_M \left[\frac{\frac{P_t^Y}{P_{t-1}^Y} \pi_t}{\left(\frac{P_{t-1}^Y}{P_{t-2}} \pi_{t-1} \right)^{\omega_{Ind}} \pi_{ss}^{1-\omega_{Ind}}} - 1 \right] \left[\frac{\pi_t P_t^Y}{\left(\frac{P_{t-1}^Y}{P_{t-2}} \pi_{t-1} \right)^{\omega_{Ind}} \pi_{ss}^{1-\omega_{Ind}} P_{t-1}^Y} \right].$$

Since all firms arrive at this same optimal pricing equation, we can drop the firm index (i) and obtain from above

$$0 = (1-\tau_t)(1-\epsilon_M) Y_t + \lambda_t^Y \left[-\frac{-\epsilon_M}{P_t^Y} Y_t \right] - (1-\tau_t) Y_t DAC_t$$

$$+ \frac{1}{1+r_{t+1}} (1-\tau_{t+1}) \frac{P_{t+1}^Y}{P_t^Y} Y_{t+1} DAC_{t+1}$$

$$\Leftrightarrow DAC_t = (1-\epsilon_M) + \epsilon_M \frac{\lambda_t^Y}{P_t^Y (1-\tau_t)} + \frac{1}{1+r_{t+1}} \frac{Y_{t+1}}{Y_t} \frac{P_{t+1}^Y}{P_t^Y} \frac{1-\tau_{t+1}}{1-\tau_t} DAC_{t+1}$$

3. $\frac{\partial L}{\partial BN_t} = 0$ yields

$$0 = \Delta_t^{DIV} (1 + \lambda_t^B - (1-\tau_t)\chi_{BN} \left(\frac{BN_t}{BN_{t-1}} - 1 \right) \frac{BN_t}{BN_{t-1}})$$

$$-\Delta_{t+1}^{DIV} (1-\tau_{t+1}) \chi_{BN} \left(\frac{BN_{t+1}}{BN_t} - 1 \right) \frac{(BN_{t+1})^2}{(-1)(BN_t)^2}$$

$$\Leftrightarrow \lambda_t^B = -1 + (1-\tau_t) DAC_t^{BN} - \frac{1-\tau_{t+1}}{1+r_{t+1}} DAC_{t+1}^{BN} \frac{BN_{t+1}}{BN_t}$$

where $DAC_t^{BN} = \chi_{BN} \left(\frac{BN_t}{BN_{t-1}} - 1 \right) \frac{BN_t}{BN_{t-1}}$. In the absence of new borrowing adjustment costs ($\chi_{BN} = 0$), it holds that $\lambda_t^B = -1$.

4. $\frac{\partial \mathcal{L}}{\partial B_t} = 0$ yields

$$0 = -\Delta_t^{DIV} \lambda_t^B - \Delta_{t+1}^{DIV} (1-\tau_{t+1})(R_t^L RP_t^B - 1 + R_t^L \frac{\partial RP_t^B}{\partial B_t} B_t)/\pi_{t+1} + \Delta_{t+1}^{DIV} \frac{\lambda_{t+1}^B}{\pi_{t+1}}$$
$$\Leftrightarrow -\lambda_t^B (1+r_{t+1})\pi_{t+1} + \lambda_{t+1}^B = (1-\tau_{t+1})(R_t^L RP_t^B (1+\xi_B b_t) - 1)$$

5. $\frac{\partial L}{\partial Inv_t} = 0$ yields

$$0 = -\Delta_t^{DIV} P_t^I - \Delta_t^{DIV}(1-\tau_t)\left(\chi_{Inv}(\frac{Inv_t}{Inv_{t-1}} - 1)Inv_t/Inv_{t-1} + \frac{\chi_{Inv}}{2}(\frac{Inv_t}{Inv_{t-1}} - 1)^2\right)$$
$$+\Delta_t^{DIV} \lambda_t^K + \Delta_t^{DIV} \frac{P_t^I \lambda_t^{K^\tau}}{\pi_{t+1}} - \Delta_{t+1}^{DIV}(1-\tau_{t+1})\chi_{Inv}(\frac{Inv_{t+1}}{Inv_t} - 1)Inv_{t+1}\frac{-Inv_{t+1}}{(Inv_t)^2}$$
$$\Leftrightarrow P_t^I = -(1-\tau_t)\left(\chi_{Inv}(\frac{Inv_t}{Inv_{t-1}} - 1)Inv_t/Inv_{t-1} + \frac{\chi_{Inv}}{2}(\frac{Inv_t}{Inv_{t-1}} - 1)^2\right)$$
$$+\lambda_t^K + \frac{P_t^I \lambda_t^{K^\tau}}{\pi_{t+1}} + \frac{(1-\tau_{t+1})}{1+r_{t+1}}\chi_{Inv}(\frac{Inv_{t+1}}{Inv_t} - 1)Inv_{t+1}\frac{Inv_{t+1}}{(Inv_t)^2}$$

where we have used

$$\Delta_{t+1}^{DIV}/\Delta_t^{DIV} = \left(\prod_{i=1}^{t+1} \frac{1}{1+r_i}\right) / \left(\prod_{i=1}^{t} \frac{1}{1+r_i}\right) = \frac{1}{1+r_{t+1}}.$$

6a. $\frac{\partial L}{\partial K_{t+1}} = 0$ yields

$$0 = -\Delta_t^{DIV} \lambda_t^K + \Delta_{t+1}^{DIV} \lambda_{t+1}^K (1-\delta)) + \Delta_{t+1}^{DIV} \lambda_{t+1}^Y \alpha_M \frac{Y_{t+1}}{K_{t+1}}$$
$$\Leftrightarrow \lambda_t^K (1+r_{t+1}) = \lambda_{t+1}^K (1-\delta) + \lambda_{t+1}^Y \alpha_M \frac{Y_{t+1}}{K_{t+1}}$$

6b. $\frac{\partial L}{\partial K_{t+1}^\tau} = 0$ yields

$$0 = -\Delta_t^{DIV} \lambda_t^{K^\tau} + \Delta_{t+1}^{DIV} \frac{\lambda_{t+1}^{K^\tau}(1-\delta_\tau)}{\pi_{t+2}} + \Delta_{t+1}^{DIV} \tau_{t+1}\delta_\tau$$
$$\Leftrightarrow \lambda_t^{K^\tau}(1+r_{t+1}) = \frac{\lambda_{t+1}^{K^\tau}(1-\delta_\tau)}{\pi_{t+2}} + \tau_{t+1}\delta_\tau$$

Note, that forward iteration of this expression yields $\lambda_t^{K^\tau} = \sum_{j=0}^{\infty}(\frac{1}{1+r_{t+1+j}}\tau_{t+1+j}\delta^\tau \prod_{i=0}^{j} \frac{1-\delta^\tau}{\pi_{t+2+i}}) > 0$. Hence, the tax-relevant capital stock has a positive shadow value and is thus beneficial to hold for firms. In the steady state, the shadow value of capital is given by $\lambda^{K^\tau} = \frac{\tau\delta^\tau}{1+r-(1-\delta^\tau)/\pi} > 0$.

We can rewrite the envelope condition on the physical capital stock under the following simplifying assumptions: (i) no investment and price adjustment cost, (ii) constant relative investment price. We then obtain the expression

$$\begin{aligned}
\lambda_t^K(1+r_{t+1}) &= \lambda_{t+1}^K(1-\delta) + \lambda_{t+1}^Y \alpha_M \frac{Y_{t+1}}{K_{t+1}} \\
\overset{\text{Price FOC}}{\Leftrightarrow} \frac{\epsilon_M - 1}{\epsilon_M} P_{t+1}^Y \frac{\partial Y_{t+1}}{\partial K_{t+1}} &= \frac{1}{1-\tau_{t+1}} \left[\lambda_t^K(1+r_{t+1}) - \lambda_{t+1}^K(1-\delta)\right] \\
\overset{\text{Inv. FOC}}{\Leftrightarrow} \frac{\epsilon_M - 1}{\epsilon_M} P_{t+1}^Y \frac{\partial Y_{t+1}}{\partial K_{t+1}} &= \frac{P^I}{1-\tau_{t+1}} \left[(1 - \frac{\lambda_t^{K^\tau}}{\pi_{t+1}})(1+r_{t+1}) - (1 - \frac{\lambda_{t+1}^{K^\tau}}{\pi_{t+2}})(1-\delta)\right] \\
\overset{\text{Tax stock FOC}}{\Rightarrow} \frac{\epsilon_M - 1}{\epsilon_M} P_{t+1}^Y \frac{\partial Y_{t+1}}{\partial K_{t+1}} &= P^I \left[\frac{r_{t+1}}{1-\tau_{t+1}} + \delta + \frac{\tau_{t+1}}{1-\tau_{t+1}} \left(\delta - \frac{\delta_\tau}{\pi_{t+1}}\right)\right. \\
&+ \left. \frac{\lambda_{t+1}^{K^\tau}}{(1-\tau_{t+1})\pi_{t+2}} \left(\frac{\delta_\tau}{\pi_{t+1}} - \delta + \frac{\pi_{t+1}-1}{\pi_{t+1}}\right)\right].
\end{aligned}$$

Following Sandmo (1974) we can interpret the right-hand side of the equation as the user cost of capital, which equals the marginal product of capital (l.h.s.) in the optimum.[52]

[52]In Sandmo (1974) firms are perfectly competitive such that the mark-up term collapses to one.

D Semi-elasticity of investment to a corporate profit tax cut

Using the steady-state value of the shadow price of the taxable capital stock, see appendix C, we can express the steady-state price of capital as

$$
\begin{aligned}
P^K &= P^I\left[\frac{r}{(1-\tau)}+\delta+\frac{\tau}{1-\tau}\left(\delta-\frac{\delta_\tau}{\pi}\right)+\frac{\lambda^{K^\tau}/\pi}{1-\tau}\left(1-\delta-\frac{1-\delta_\tau}{\pi}\right)\right]\\
&= P^I\left[\frac{r}{(1-\tau)}+\delta+\frac{\tau}{1-\tau}\left(\delta-\frac{\delta_\tau}{\pi}\right)+\frac{\tau}{1-\tau}\frac{\delta_\tau}{\pi}\frac{1-\delta-(1-\delta_\tau)/\pi}{1+r-(1-\delta_\tau)/\pi}\right]\\
&= \frac{P^I}{(1-\tau)}\left[r+\delta(1-\tau)+\tau(\delta-\frac{\delta_\tau}{\pi})+\tau\frac{\delta_\tau}{\pi}\frac{\pi-\delta\pi-1+\delta_\tau}{\pi+r\pi-1+\delta_\tau}\right]\\
&= \frac{P^I}{(1-\tau)}\left[r+\delta-\tau\frac{\delta_\tau}{\pi}+\tau\frac{\delta_\tau}{\pi}\frac{\pi-\delta\pi-1+\delta_\tau}{\pi+r\pi-1+\delta_\tau}\right]\\
&= \frac{P^I}{(1-\tau)}\frac{(r+\delta)(\pi+r\pi-1+\delta_\tau)+\tau\frac{\delta_\tau}{\pi}(\pi-\delta\pi-1+\delta_\tau-\pi-r\pi+1-\delta_\tau)}{\pi+r\pi-1+\delta_\tau}\\
&= \frac{P^I}{(1-\tau)}\frac{(r+\delta)(\pi+r\pi-1+\delta_\tau)+\tau\frac{\delta_\tau}{\pi}(-\delta\pi-r\pi)}{\pi+r\pi-1+\delta_\tau}\\
&= \frac{P^I}{(1-\tau)}\frac{(r+\delta)(\pi+r\pi-1+\delta_\tau-\tau\delta_\tau)}{\pi+r\pi-1+\delta_\tau}
\end{aligned}
$$

Note that this cost of capital equation can be rearranged to express it as a function of the net present value of the depreciation shield per unit of investment A:

$$P^K=\frac{P^I}{1-\tau}(r+\delta)(1-A), \tag{20}$$

where[53]

$$A = \frac{\tau\delta_\tau}{\pi r+\pi}\sum_{i=0}^{\infty}\left(\frac{1-\delta_\tau}{\pi+r\pi}\right)^i=\frac{\tau\delta_\tau}{\pi r+\pi}\frac{1}{1-\frac{1-\delta_\tau}{\pi+r\pi}}=\frac{\tau\delta_\tau}{\pi+r\pi-1+\delta_\tau}.$$

We now derive the derivative of the steady-state user cost of capital with respect to the corporate

[53] Consider an investment I_0 made in period $t=0$. In period $t=1$, following the tax-stock capital accumulation in equation (12), the real value of that investment for tax purposes is given by I_0/π. From the perspective of period $t=0$, the value of the tax depreciation shield in $t=1$ is then given by $\tau\delta_\tau I_0/\pi\frac{1}{1+r}$, where the last term follows from discounting the future one period ahead. In period $t=2$, the initial investment has depreciated at the tax allowance rate δ_τ, implying a NPV of the tax depreciation shield (in that period only) of $\tau\delta_\tau(1-\delta_\tau)\frac{I_0}{\pi^2(1+r)^2}$. Overall, summing over all future periods, we obtain a NPV of the tax depreciation shield per unit of investment (i.e. by dividing by I_0).

profit tax rate.

$$\begin{aligned}
\frac{\partial P^K}{\partial \tau} &= \frac{P^I}{(1-\tau)^2}\left[r + \left(\delta - \frac{\delta_\tau}{\pi}\right) + \frac{\delta_\tau}{\pi}\frac{1-\delta-(1-\delta_\tau)/\pi}{1+r-(1-\delta_\tau)/\pi}\right] \\
&= \frac{P^I}{(1-\tau)^2}\left[r+\delta-\frac{\delta_\tau}{\pi}+\frac{\delta_\tau}{\pi}\frac{\pi-\delta\pi-1+\delta_\tau}{\pi+r\pi-1+\delta_\tau}\right] \\
&= \frac{P^I}{(1-\tau)^2}\frac{(r+\delta)(\pi+r\pi-1+\delta_\tau)+\frac{\delta_\tau}{\pi}(\pi-\delta\pi-1+\delta_\tau-\pi-r\pi+1-\delta_\tau)}{\pi+r\pi-1+\delta_\tau} \\
&= \frac{P^I}{(1-\tau)^2}\frac{(r+\delta)(\pi+r\pi-1+\delta_\tau)+\frac{\delta_\tau}{\pi}(-\delta\pi-r\pi)}{\pi+r\pi-1+\delta_\tau} \\
&= \frac{P^I}{(1-\tau)^2}\frac{(r+\delta)(\pi+r\pi-1)}{\pi+r\pi-1+\delta_\tau}
\end{aligned}$$

Dividing $\frac{\partial P^K}{\partial \tau}$ by P^K we obtain

$$\begin{aligned}
\frac{\partial P^K}{\partial \tau}/P^K &= \frac{1-\tau}{(1-\tau)^2}\frac{\pi+r\pi-1}{\pi+r\pi-1+\delta_\tau-\tau\delta_\tau} \\
&= \frac{\pi+r\pi-1}{(\pi+r\pi-1)(1-\tau)+\delta_\tau(1-\tau)^2}
\end{aligned}$$

which yields the elasticity stated in the main text. Given the Cobb-Douglas production function, we obtain

$$P^K = \frac{\epsilon-1}{\epsilon}P\frac{\partial Y}{\partial K} = \frac{\epsilon-1}{\epsilon}P\alpha\left(\frac{K}{N}\right)^{\alpha-1} \Leftrightarrow K = N\left(P^K/\widetilde{\alpha}\right)^{1/(\alpha-1)} \tag{21}$$

where $\widetilde{\alpha} = \alpha\frac{\epsilon-1}{\epsilon}P$. For simplicities sake, we assume

$$\frac{\partial N}{\partial \tau} = 0. \tag{22}$$

In other words, we assume that only capital adjusts to the tax rate change, while employment remains constant. Given $I = \delta K$ in steady state, the semi-elasticity of investment with response to tax changes is given by

$$\begin{aligned}
\epsilon_\tau^I &= \frac{\partial I}{\partial \tau}/I = \frac{\partial(\delta K)}{\partial \tau}/\delta K = \frac{\partial K}{\partial \tau}/K \\
&\overset{(22)}{=} \frac{N}{K}\frac{1}{\alpha-1}\left(P^K/\widetilde{\alpha}\right)^{1/(\alpha-1)-1}\frac{1}{\widetilde{\alpha}}\frac{\partial P^K}{\partial \tau} \\
&\overset{(21)}{=} \left(P^K/\widetilde{\alpha}\right)^{-1/(\alpha-1)}\frac{1}{\alpha-1}\left(P^K/\widetilde{\alpha}\right)^{1/(\alpha-1)-1}\frac{1}{\widetilde{\alpha}}\frac{\partial P^K}{\partial \tau} \\
&= \left(P^K/\widetilde{\alpha}\right)^{-1}\frac{1}{\alpha-1}\frac{1}{\widetilde{\alpha}}\frac{\partial P^K}{\partial \tau} = \frac{1}{\alpha-1}\epsilon_\tau^{P^K}.
\end{aligned}$$

E Comparison with Sandmo (1974)

With respect to our setup in section 2, Sandmo (1974) makes two assumptions simplifying the analysis. First, Sandmo implicitly assumes that the capital stock for tax purposes equals the physical capital stock at any point in time, despite a higher tax depreciation rate. This ultimately leads to λ^{K^τ} dropping out of the equation. Second, Sandmo assumes a model without inflation.

We can replicate the expression for the user cost of capital in Sandmo (1974) by imposing these assumptions on our model. Hence, we drop the constraint on the capital stock for tax purposes in equation (12) from the model and use the physical capital stock as the basis for the depreciation allowance in equation (11). Furthermore, we assume, that inflation in the model is given by $\pi = 1$. Deriving the analogous optimality condition as in section 2 under these simplified conditions yields

$$P^K = P^I \left[\frac{r}{(1-\tau)} + \delta + \frac{\tau}{1-\tau} (\delta - \delta_\tau) \right] \tag{23}$$

which is equivalent to the specification in Sandmo (1974). Note that the sign of the effect of a tax cut on the cost of capital (and investment) in this specification is ambiguous and depends on δ_τ. If the latter is large enough, a corporate tax cut can lead to an increase in the cost of capital and depress investment.

F Neutrality of the ASE tax system with respect to taxation of dividends

In this section, we show that the ASE tax system is neutral with respect to dividend taxation. The following calculations are from the perspective of Norwegian investors. Although foreign investors pay dividend tax to their home countries, as a rule, the Norwegian distributing company must deduct 25 percent withholding tax on dividends. The tax rate for foreign investors may however be reduced in accordance with tax treaties or Norwegian tax regulations, see The Norwegian Tax Administration.

As derived in Aursland et al. (2019), the real market interest rate r_t in NORA is an endogenous function of the interest rate at household level, financial fees (a trick introduced to model the equity risk premium in a perfect foresight model), and the dividend taxation rate. Specifically, the optimal decision with respect to holding stocks at household level yields the following expression:

$$r_t = \frac{(1 + F_t^S) r_t^{hh} - 1/\pi_t \tau_t^D (1 + RRA_t)}{1 - \tau_t^D} - 1, \tag{24}$$

where F_t^S are financial fees paid for holding stock (expressed as a percentage of the stock's value), r_t^{hh} is the household-level real after tax interest rate on deposits introduced below, τ_t^D is total tax rate on dividends (given by the product of household-level ordinary income tax and the scale-up factor on shareholder income), and RRA_t is risk-free return allowance, also introduced below.

The household-level real after tax interest rate on deposits reflects households' discounting of future cash flows and is given by

$$r_t^{hh} = \frac{1}{\pi_t} + \frac{(1 - \tau_t^{OIH}) R_t}{\pi_t} - 1. \tag{25}$$

This reflects the fact that NOK 1 invested in risk-free deposits earns interest at a nominal risk-free interest rate R_t (which is set by the central bank in line with a standard Taylor rule) minus taxes (nominal interest income is taxed at the household ordinary income tax rate τ_t^{OIH}) and adjusted for inflation.

According to the Norwegian law, the risk-free return allowance is set as the nominal after-tax risk-free return, i.e.

$$RRA_t = (1 - \tau_t^{OIH}) R_{t-1}$$

Thus dividends are only taxed on amounts in excess of the after-tax return on risk-free assets.

While equation (24) suggests at first sight that the market interest rate responds to changes in the level of dividend taxation (and thus to the scale-up factor), it can be shown by inserting the expressions for r_t^{hh} and RRA_t in (24), that

$$r_t = (1 + r_t^{hh})(1 + \frac{F_t^S}{1 - \tau_D}) - 1 = r_t^{hh} + RP_t, \tag{26}$$

where $RP_t = \frac{(1+r_t^{hh})F_t^S}{1-\tau_D}$ is the equity premium. So far we did not say much about the functional form of the financial fees term. To reproduce the important property that the equity risk premium $RP_t \propto (1 - \tau_{t+1})$,[54] we require that the financial fees have the functional form

$$F_t^S = F_{SS}^S \cdot \frac{1 - \tau_{t+1}}{1 - \tau_{SS}} \cdot \frac{1 - \tau_{t+1}^D}{1 - \tau_{SS}^D} \cdot \frac{1 + r_{SS}^{hh}}{1 + r_t^{hh}}. \tag{27}$$

Note that we have assumed that the equity premium is independent of the dividend tax, which

[54] The relation between the equity premium and the corporate tax rate can be easily derived within the stochastic version of the NORA model. See also the related discussion in Devereux and Freeman (1991).

is a simplifying assumption that partly captures the reality that not all of those who invest in Norwegian equities are subject to the Norwegian dividend tax.[55] A consequence of this assumption is that the market interest rate is independent of the dividend tax, in line with the underlying principle of an allowance for shareholder equity (ASE) in the tax system. Hence, changing the scale-up factor (i.e. the dividend tax rate) has no effect on the user cost of capital.

G Neutrality of the ACE tax system and non-neutrality of the ASE tax system with respect to the corporate tax rate

In the following we show why the user cost of capital is not neutral with respect to the corporate income tax in the ASE tax system, in contrast to the ACE tax system. In the absence of equity risk premium, Devereux and Freeman (1991) (see page 12 in their Appendix) derive the user cost of capital in the ACE system to have the form

$$P^K_{ACE} = \frac{r^{\mathrm{rf}} - r^{\mathrm{rf}}\tau}{1-\tau} + \delta = r^{\mathrm{rf}} + \delta, \tag{28}$$

where the r^{rf} is the risk-free real discount rate (an expression for which can be obtained from equation (24) by setting $RRA = 0$ and $F = 0$), δ is depreciation rate, and τ is corporate tax rate. Note that we set $P^I = 1$ so the notation is consistent with our main text. In this discussion we, however, abstract from the details of the tax depreciation shield. The subtraction of $r^{\mathrm{rf}}\tau$ in the numerator represents the impact on the user cost from the allowance for corporate equity in the ACE system. While Devereux and Freeman (1991) derive the equation under the assumption that there is no equity premium, the derivation works equally well in the presence of equity premium RP, and results to

$$P^K_{ACE} = \frac{r - r^{\mathrm{rf}}\tau}{1-\tau} + \delta, \tag{29}$$

where r is the real market interest rate, which includes a risk premium. Substituting the formulas from (24) and (25), we eventually obtain

$$P^K_{ACE} = \frac{1}{\pi}\left(1 + \frac{1-\tau^{OIH}}{1-\tau^{D}}R\right) - 1 + \frac{RP}{1-\tau} + \delta. \tag{30}$$

The nominal deposit rate, or the risk free-interest rate, R, does not depend on the corporate tax rate and as discussed in the previous section, $RP \propto (1-\tau)$ so that P^K_{ACE} is neutral to the corporate tax rate.

[55] When all the investors are domestic and subject to the same dividend taxation, the equity premium that can be derived from the stochastic model would be proportional to $(1-\tau_D)(1-\tau)$. In other words, the equity premium would decrease when dividend tax increases.

In the ASE tax system the subraction of $r^{\mathrm{rf}}\tau$ is absent from the required return formula and the investor's required return given by equation (26) is different than in a non-ASE tax system. Hence, dropping $-\tau r^{\mathrm{rf}}$ and substituting r in equation (29) using (26), we obtain

$$P^K_{ASE} = \frac{r^{hh} - 1 + RP}{1-\tau} + \delta. \tag{31}$$

Recall that, from (25) the household-level real after tax interest rate on deposits r^{hh}

$$r^{hh} = \frac{1}{\pi}\Big(1 + (1-\tau^{OIH})R\Big) - 1, \tag{32}$$

where R is the nominal deposit rate. Hence,

$$P^K_{ASE} = \frac{\frac{1}{\pi}\Big(1 + (1-\tau^{OIH})R\Big) - 1 + RP}{1-\tau} + \delta. \tag{33}$$

The risk premium RP is again proportional to $(1-\tau)$ so that the corresponding part is neutral to corporate tax. Note that the nominal risk free interest rate R is endogenous and responds to a change in household ordinary income tax such that $R \propto (1-\tau^{OIH})^{-1}$, see equation 24. Hence, the ASE tax system is not neutral to corporate income tax (nor to the combined reduction in household and corporate income tax). As discussed in the previous section, the ASE tax system is neutral with respect to dividend tax if and only if RP is independent of the dividend tax.

For a common tax system without allowance for corporate equity, the expression for required return looks like

$$P^K = \frac{r^{\mathrm{rf}} + RP}{1-\tau} + \delta, \tag{34}$$

where r^{rf} again represents the risk-free part of the discount rate obtained from (24) assuming $RRA = 0$ and $F = 0$. After some algebra we can write

$$1 + r^{\mathrm{rf}} = \frac{1}{\pi}\Big(1 + \frac{1-\tau^{OIH}}{1-\tau^{D}}R\Big). \tag{35}$$

Hence,

$$P^K = \frac{\frac{1}{\pi}\Big(1 + \frac{1-\tau^{OIH}}{1-\tau^{D}}R\Big) - 1 + RP}{1-\tau} + \delta, \tag{36}$$

Here the factor $(1-\tau^{OIH})R$ is invariant to tax changes. Hence P_K is both non-neutral with respect to a change in the dividend tax and a simultaneous change in the corporate income tax and the household ordinary income tax.

H Government budget balance

Norway does not borrow money to finance government spending. However, the government's total revenue from the petroleum industry is transferred to the GPFG. Withdrawals from the fund are used to cover the structural non-oil fiscal deficit so that the government budget constraint can be written as

$$T_t + OFW_t = G_t, \tag{37}$$

where OFW_t denotes withdrawals from the GPFG. According to the fiscal rule (Norwegian: handlingsregelen) a maximum of 3 % of the fund's value, equivalent to the forecast real return, can be withdrawn annually. T_t denotes tax revenues excluding taxes on petroleum given by,

$$\begin{aligned} T_t = \; & \underbrace{T_t^L}_{\text{Lump-sum tax}} + \underbrace{C_t(\tau_t^C + F_t^C/P_t)}_{\text{Consumption taxes and fees}} + \underbrace{(W_t N_t^P + W_t^G N_t^G)\tau_t^{SSF}}_{\text{Social security contributions of employers}} \\ & + \underbrace{(W_t N_t^P + W_t^G N_t^G + UB_t(L_t - E_t) + TR_t + \frac{DP_{t-1}}{\pi_t}(R_{t-1} - 1) - TD^{OIH})\tau_t^{OIH}}_{\text{Ordinary income tax on personal income}} \\ & + \underbrace{(W_t N_t^P + W_t^G N_t^G + UB_t(L_t - E_t) + TR_t - TD^{LS})(\tau_t^{LS} + \tau_t^{SSH})}_{\text{Additional taxes on Labor income and transfers}} \\ & + \underbrace{(\Pi^{M,TB} + \Pi^{S,TB})\tau_t^{OIF}}_{\text{Corporate income taxation}} + \underbrace{\left(DIV_t + AV_t - RRA_t P_{t-1}^E\right)\alpha_t^{OIH}\tau_t^{OIH}}_{\text{Dividend and capital gains tax}}, \end{aligned} \tag{38}$$

and the government primary expenditures are given by

$$\begin{aligned} G_t = \; & \underbrace{P_t^{G^C} G_t^C}_{\text{Government purchases}} + \underbrace{P_t^I G_t^I}_{\text{Government investment}} + \underbrace{UB_t(L_t - E_t)}_{\text{Unemployment benefits}} \\ & + \underbrace{TR_t + AVT_t}_{\text{Lump-sum transfers}} + \underbrace{W_t^G N_t^G(1 + \tau_t^{SSF})}_{\text{Government wage bill}}. \end{aligned} \tag{39}$$

The tax changes that we consider affect T_t and G_t, so that the budget constraint will not hold unless we assume adjustment in some other financing instrument. As the means of financing we consider what Aursland et al. (2020) call oil financing, which corresponds to allowing OFW_t to adjust in the above equation. This comes at no meaningful macroeconomic cost. The oil financing serves to isolate the effects of the tax cut from the effect of the offsetting fiscal maneuver. This enables better comparability with empirical results that rely on cross-country differences in tax rates rather than financed tax reforms. The theoretical literature often assumes transfer financing. If we use transfer financing, the results will be qualitatively similar. Quantitatively, the self-financing rates will be higher in the benchmark case and lower in the no-relocation case, increasing the wedge between the two scenarios.

I Additional graphs and tables

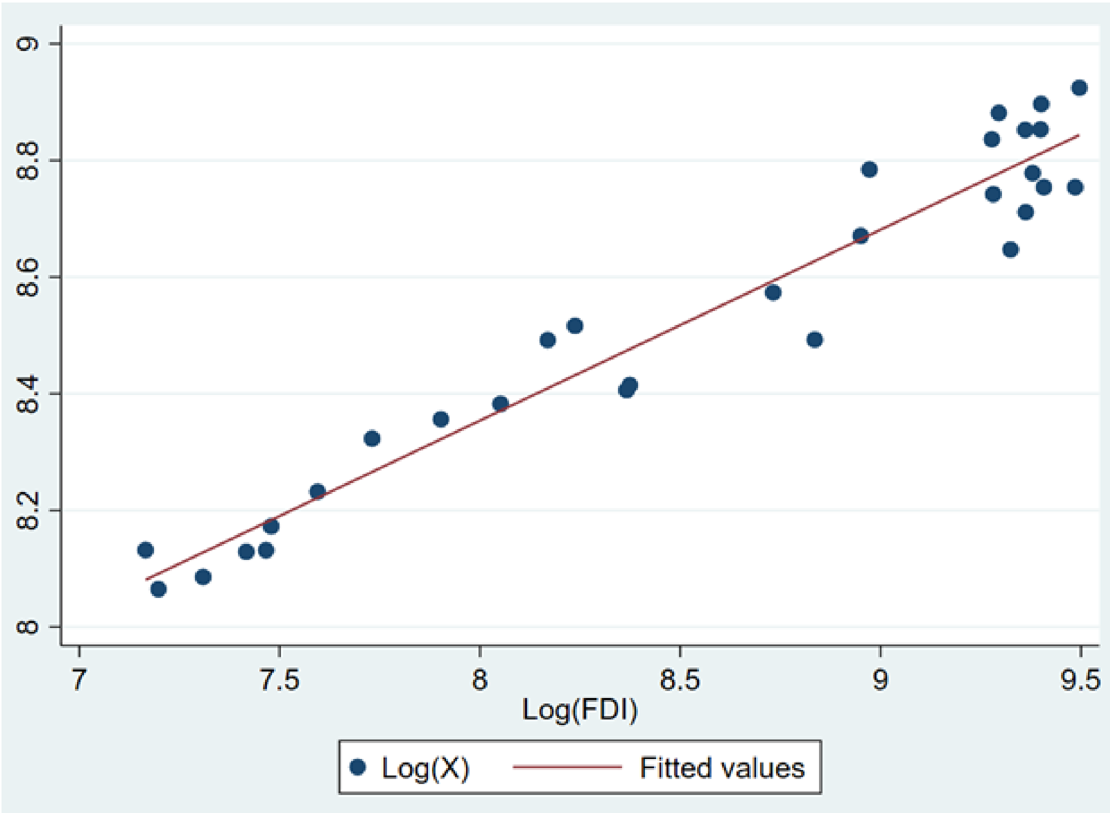

Figure S5: Exports and inward FDI. The graph shows the linear fit $\ln(X) = 0.327(0.016)\ln(FDI) + 5.737(0.136)$, with standard errors in parentheses, $N = 30$ and $R^2 = 0.94$. The projection coefficient estimate for the elasticity of exports with respect to inward FDI stock is 0.327. Here X denotes real exports of goods and services excluding oil and natural gas (Source: SSB Table 07336) deflated by the Norwegian consumer price index. FDI denotes real inward FDI stock (Source: UNCTAD World Investment Report) converted to NOK and deflated by the Norwegian consumer price index. The estimation period is 1990-2019.

Table S2: Financing contributions from each item in the government budget when lump-sum taxes are used for financing

	Benchmark	No relocation	Profit shifting
Ex-ante fiscal impulse	100	100	100
Income components	240	30	270
Corporate profit tax	20	-1	32
Consumption tax	69	0	77
Ordinary income tax	83	31	87
of which labor income	68	1	73
of which interest income	2	1	3
of which dividend income	13	29	12
Labor surtax	21	0	22
Household social security contributions	4	0	5
Firm social security contributions	43	0	46
Expenditure components	-90	0	-96
Government purchases and investment	-6	0	-6
Government employment	-81	-1	-87
Unemployment benefits	0	0	0
Government debt servicing	-3	0	-3
Oil fund withdrawals	-51	70	-74
Self-financing rate	151	30	174

Following Trabandt and Uhlig (2011), the financing contribution for budget items Z other than corporate tax revenue is calculated as $\pm\Delta Z/(TB_{SS}^{OIF}\Delta\tau_{OIF})$, where a plus sign applies to expenditure items and a minus sign applies to tax items. The self-financing contribution from the corporate tax base is calculated as $1+\Delta T/(TB_{SS}^{OIF}\Delta\tau_{OIF})$, where TB_{SS}^{OIF} is the corporate tax base (taxable income) and $\Delta\tau_{OIF}$ is the change in the corporate profit tax rate (1 pp). Benchmark = model with foreign investment and without profit shifting. No relocation = model without foreign investment and without profit shifting. Profit shifting = model with foreign investment and with profit shifting.