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Abstract

Recent events in the global political economy have led to record high levels of oil and gas prices. In the UK, this has meant (1) a cost-of-living crisis; and (2) a significant increase in profits earned by companies in the upstream UK Continental Shelf (UKCS) sector. To help fund a cost-of-living support scheme for UK households, the UK Government recently introduced a windfall tax on upstream UKCS operations. There have been concerns however that the new tax would downgrade the value of UKCS assets hence diminishing the global competitiveness of the province. In this paper, we develop an optimisation model that fully incorporates all instruments of the new UK windfall taxation regime. The model is then applied to twelve wholly new UKCS fields currently under review by the UK Government for development approval. We show that whilst the new UK windfall tax reduces field economic value for all fields, the extent of the reduction is unlikely to cause premature abandonment of the fields. Consequently, the tax would not significantly injure the global competitiveness of the province. For the UK Government, the windfall tax would raise about $ 1.97 billion in tax revenues from the new fields in question. Finally, we derive the critical oil price levels that should trigger an accelerated phase out of the windfall tax in order to maintain the global competitiveness of the UKCS province should future oil prices slump.

Key words: UKCS; Oil; Gas; Windfall; Tax; Prices

1 Introduction

Recent events in the global political economy have led to record high increases and levels in the prices of oil and gas and their derivative and associated products. The most important political economy factors causing this price trend, which is a manifestation of the imbalances in global supply and demand of petroleum products, have been (1) the Russia-Ukraine war which commenced in February 2022, with the resulting geo-political sanctions by the United States and its western allies on Russia's energy exports; (2) recovery in global oil demand following the uplift of COVID-19 lockdown restrictions in many countries, and the resulting recovery in economic activity; (3) a swift decline in global oil and gas inventory levels following cuts in OPEC+ supply; and so on (see OPEC, 2022). Figure 1 charts the significant increases and levels in oil and gas prices since 2019 as a direct consequence of the political economy factors mentioned above.

Figure 1: Crude oil and gas prices from January 2019 to July 2022, showing a significant recent spike (Source: Author plot using data from US EIA, 2022.a; US EIA, 2022.b; US EIA, 2022.c).
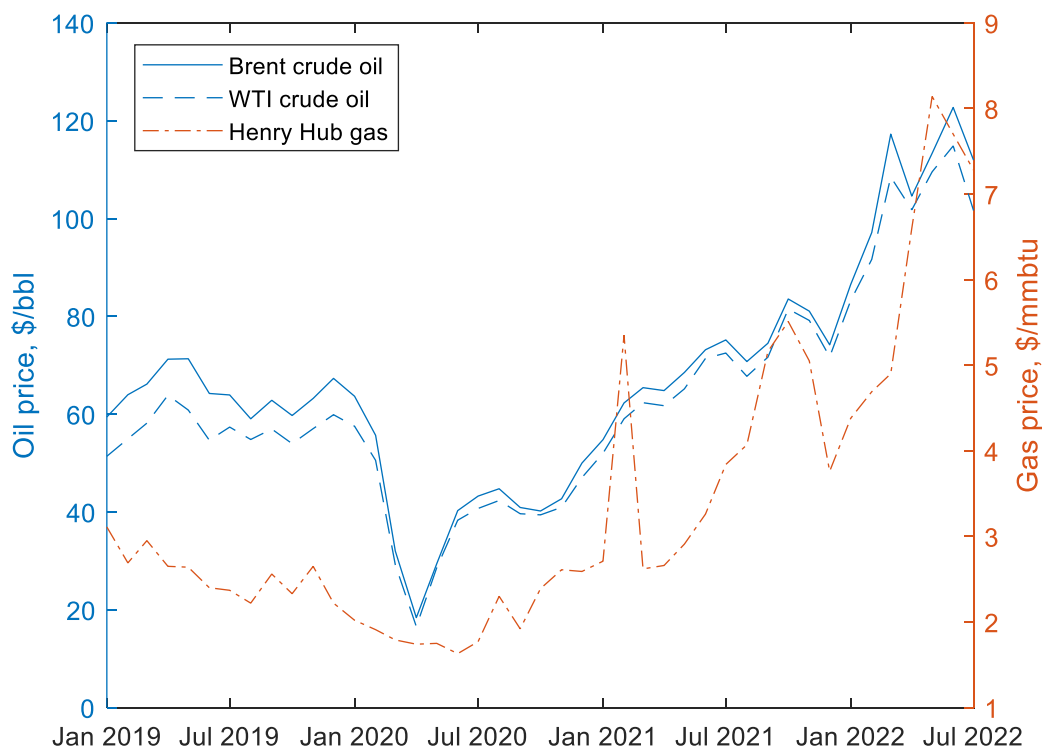
The record high increases and levels in petroleum prices have led to (1) a cost-of-living crisis in many countries including the UK; and (2) a significant increase in profits earned by the upstream petroleum sector globally, including that of the UK Continental Shelf (UKCS). UK inflation as of August 2022 was at a 40-year high rate of 10.1% hence squeezing the real income

levels of UK households (ONS, 2022.a). At the same time, the net rate of return of UKCS companies had increased from -5.9% in Q4 2020 to 18.1% in Q1 2022 (ONS, 2022.b). To help fund a cost-of-living support scheme for UK households, the UK Government introduced a new upstream petroleum taxation regime in May 2022 (later revised in November 2022), which included the imposition of a new Energy Profits Levy (see UK Government, 2022.a). This levy, which we henceforth call the windfall tax, surcharges the price-induced supernormal profits (i.e. windfall) earned by the upstream petroleum sector in the UKCS, at a rate of 35%. This is in addition to a pre-existing Ring Fence Corporation Tax rate of 30% (see UK Government, 2022.a; UK Government, 2022.b) and a Supplementary Charge rate of 10% (see UK Government, 2022.a; UK Government, 2022.c) on profits. The headline rate of tax in the new windfall taxation regime is therefore 75%, compared to the previous taxation regime's headline rate of only 40%. With the new windfall taxation regime, the UK Government hopes to raise about £40 billion from the upstream UKCS sector over the next circa five and quarter years of implementation to fund its cost-of-living support scheme.

Recognising the potential negative effects of the new windfall tax on planned and/or prospective future upstream UKCS investments, the UK Government introduced a new super-deduction style 29% investment allowance for UKCS operators as part of the tax relief incentives in the new windfall taxation regime.[1] Operators would be able to offset some of the burden of the new windfall tax by applying this allowance to reduce taxable windfall profits. The new allowance is in addition to a pre-existing investment allowance rate of 62.5% to offset against the Supplementary Charge handle (see UK Government, 2022.a; UK Government, 2022.d); and a first-year capital allowance rate of 100% to offset against all taxes (see UK Government, 2022.a; UK Government, 2022.e). The introduction of the new 29% investment allowance enhances the tax reliefs available to operators in the new windfall taxation regime relative to the previous taxation regime. The headline amount of tax relief available to UKCS operators in the previous taxation regime was 46.25 pence for every £1 invested; compared to 91.40 pence for every £1 invested in the new windfall taxation regime (see UK Government, 2022.a). The UK Government contends that the higher tax relief package in the new windfall taxation regime would encourage operators to (re)invest in the UKCS sector, leading to more UKCS jobs, greater UK energy security and wider UK economic growth.[2]

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[1] Where appropriate, we use the term 'investor' and 'operator' interchangeably.

[2] The 29% investment allowance is for tax relief on the windfall tax only. The 62.5% investment allowance is for tax relief on the supplementary charge only. The 62.5% investment allowance on the supplementary charge may only be claimed once income is accrued to the field that is subject to the allowance. The 29% investment

The new UK windfall taxation regime takes effect in January 2023 and is expected to end in March 2028, effectively making it a five and quarter year temporary fiscal measure.

Globally, there is historical precedent for the imposition of windfall taxes of different forms (e.g. as a one-off tax versus annual tax). In the UK for example, windfall taxes were imposed as far back as the 1980s when, under former conservative prime minister Margaret Thatcher, a one-off tax of 2.5% was imposed on certain bank deposits deemed to benefit from the high interest rates at the time. Also, in 1997 under former Labour prime minister Tony Blair, a one-time windfall tax was imposed on utilities deemed to have benefited from the privatisation exercise at the time (Advani et al., 2020; Nuccio, 2013; Chennells, 1997). In the United States, windfall taxes on domestic production of crude oil were introduced in 1980 with a goal to extract the super-normal profits arising from the phase out of price controls in the sector (Verleger, Jr., 1980; Knoll, 1987; McDonald, 1981). Windfall taxes have been severally examined in the literature for their impact on petroleum production (see e.g. Rao, 2018; Verleger Jr, 1980); their ability to fulfil certain guidelines of tax policy, including ability to raise revenues, efficiency, fairness and administrative compliance and feasibility (see e.g. Abdo, 2010; Chennells, 1997; Lazzari, 1990); the relative share of the windfall tax burden on consumers and producers (see e.g. McDonald, 1981); their influence on politics and governance (see e.g. Andersen and Sørensen, 2022; Borge et al. 2015; Alexeev, M. and Zakharov, 2022); and so on.

Upon the introduction of the UK windfall taxation regime, some industry stakeholders have posited that the tax would diminish the value of UKCS fields hence causing projects to be economically unviable and leading to a reduction in the competitiveness of the province. The Oil and Gas UK (OGUK), which is the leading representative body for the UK oil and gas industry, have said the windfall tax "would damage competitiveness, and discourage energy companies from investing in the UK" (see OEUK, 2022).

In this paper, we develop an optimal investment appraisal model that fully incorporates all instruments of the new UK windfall taxation regime. There are currently twelve wholly new UKCS oil and gas fields undergoing the administrative processes set by the UK Government leading to their development and subsequent production.[3] Although some of the fields were discovered decades ago, all the fields are only now going through these processes. Hence in

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allowance on the windfall tax is in contrast available to operators at the point of investment, hence making it more immediate and more generous.

[3] We do not include fields undergoing marginal changes such as enhanced oil recovery operations.

this paper, we categorise all twelve fields as new. Environmental impact assessment (EIA) reports have been submitted by the field owners to the UK Government and are currently under review. If the field EIAs are approved, applications for consent to develop the fields would also need to be submitted by the field owners for approval by the UK Government. All twelve fields are projected to be developed in 2022 or later; and are expected to have struck first oil and/or gas production in the next few years. We are specifically considering new fields because they are fully subject to all the handles of the new UK windfall taxation regime only. The twelve fields in question are broadly representative of the characteristics of the breed of new fields being discovered and developed in the mature UKCS province.

This paper contributes to the literature by providing the first examination of the effect of the newly introduced UK windfall taxation regime on upstream UKCS operations. We find that the UK windfall tax does reduce field economic values. However, the extent of the reduction is insufficient to cause the fields to be uneconomic.[4] The tax more generally is hence unlikely to cause premature abandonment of sufficiently prolific new fields in the UKCS. Consequently, the tax would not irredeemably injure the global competitiveness of the province. For the UK Government Exchequer, the windfall tax would raise about $1.97 billion from the twelve new fields under consideration. Finally, the UK Government in the original legislation underpinning the introduction of the windfall tax indicated that the tax would be phased out when oil and gas prices return to historically more normal levels (UK Parliament, 2022). These levels however had not been specified in the legislation. We derive the critical oil price levels required for all fields to be economically viable. Our focus on critical oil prices is informed by the observation that oil prices significantly influence the price of other energy products including gas (see e.g. Caporin and Fontine, 2017; Bhattacharyya 2019; Brigida, 2014; Mu, 2019). Our analysis on critical oil prices may be used by the UK Government as a guide to trigger an accelerated phase out of the windfall tax should future oil prices slump ahead of the intended windfall tax end date of March 2028. This would help maintain the global competitiveness of the UKCS province.

The rest of the paper is organised as follows; Section 2 introduces our methodology, with a description of our model and underlying assumptions. Section 3 introduces our data whilst Section 4 introduces our results. Section 5 concludes the paper.

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[4] Using the NPV metric, all twelve wholly new fields continue to be economically viable after the imposition of the windfall tax. Using the discounted profitability index metric, eleven of the fields continue to be economically viable.

2 Methodology

2.1 Model setting and assumptions

It is important to underscore at the outset that the UK Government distinguishes between different classes of upstream petroleum operators for tax treatment purposes. This has important implications for the economics of fields in the UKCS province. Consequently, modelling the economics of the twelve wholly new petroleum fields under consideration requires explicit assumptions about the tax profiles of the operators owning these fields, namely whether they have sufficient pre-existing tax exposures with the UK Government Exchequer to the extent that they are eligible for immediate and substantive first-year capital and investment tax reliefs, or not.

We do not have commercially sensitive information about the UK tax positions of the individual field operators and owners of the twelve new fields. However, the recent history of relatively low global petroleum prices, specifically in the period between 2014 and 2021, has meant that there has been a significant erosion of the net cashflow positions of companies in the UKCS sector. The net rate of return for UKCS companies between Q1 2020 to Q2 2021 for example has been negative (ONS, 2022.b).[5] The likelihood therefore is that, similar to new UKCS operators, many established operators have little to non-existent pre-existing tax positions on their portfolio of active and producing fields in that period, such that they are presently ineligible to allocate any capital and/or investment tax allowances from new fields towards substantive tax reliefs on pre-existing fields. For this reason, we assume that all capital and investment tax allowances for the twelve new fields under consideration would be staggered over the production horizons of the fields for purposes of annual tax reliefs. The implication of this assumption regarding the treatment of tax is that the economics of these fields would be relatively diminished compared to a scenario where the operators are assumed to have pre-existing tax paying positions for full and immediate first-year tax reliefs. In this regard, our approach to the assessment of the economics of the fields may be presumed to be conservative.

As we have assumed investors with no tax positions against which to fully set capital allowances in the first year, an additional instrument of upstream UKCS taxation becomes

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[5] Also, the average Brent crude oil spot price in the period Jan 2014 – Jan 2021 for example was $55.34/bbl; which is lower than the more recent (i.e. July 2021 – July 2022) average of $93.28/bbl (see EIA, 2022.a).

relevant. This is the Ring Fence Expenditure Supplement, introduced to supplement the value of unused capital allowances carried forward intertemporally to maintain their time value of money (see UK Government, 2022.f). The Ring Fence Expenditure Supplement is currently set at 10%, and operators are allowed to claim it for up to ten accounting periods. We capture the Ring Fence Expenditure Supplement in our modelling.

Having made the above assumptions, we now introduce a mathematical optimisation model to determine the effect of the new UK upstream windfall taxation regime, which includes the newly introduced windfall tax and the super-deduction investment allowance, on the economic outlook of the twelve new UKCS fields. The mathematical model is based on an optimal discounted cashflow (DCF) framework.[6] We use the net present value (NPV) and the discounted profitability index (DPI) metrics for our assessment. The North Sea Transition Authority (NSTA), which is the UK Government body in charge of regulating the UKCS sector, recommends the DCF approach and the two mentioned metrics for their 'satisfactory expected commercial return (SECR)' assessment of petroleum fields in the UKCS (OGA, 2018).[7] The metrics are consistent with the stated maximisation of economic recovery (MER) goal of the NSTA and allied upstream petroleum industry institutions and have been widely used to assess the economic viability of petroleum fields around the world (see OGA, 2018; OGA, 2016; OGUK, 2021; Abdul-Salam et al., 2021; Abdul-Salam et al., 2022; Osmundsen et al., 2022).[8]

2.1.1 Equations defining capital and investment tax allowances

Following the above model assumption and setting, let i represent an oil and/or gas field and t represent time. Now let $\alpha_{i,t}$ represent an endogenous binary variable indicating the production status of field i in period t, such that;

$$\alpha_{i,t} \leq \alpha_{i,t-1} \ \forall \ i, t = 2, \dots, T \tag{1}$$

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[6] There are other frameworks for assessing the economics of oil and gas operations including decision tree analysis (see e.g. Newendorp and Schuyler, 1976), real options analysis (see e.g. Abdul-Salam, 2022), etc.

[7] The SECR is an objective and pragmatic safeguard, with a targeted number of metrics. The NSTA defines the SECR as "an expected post-tax return that is reasonable having regard to all the circumstances including the risk and the nature of the investment (or other funding as the case may be)…" (OGA, 2018).

[8] The NSTA, formerly the UK Oil and Gas Authority (OGA), in OGA (2016) define economically recoverable reserves as 'those resources which could be recovered at an expected (pre-tax) market value greater than the expected (pre-tax) resource cost of their extraction, where costs include both capital and operating expenditures but exclude sunk costs and costs (such as interest charges) which do not reflect current use of resources. In bringing costs and revenues to a common point for comparative purposes a 10% real discount rate will be used'.

Binary variable $\alpha_{i,t}$ captures the endogenous production status of a field such that it takes a value of 1 if production in field i in period t is endogenously determined to be optimal, and 0 otherwise. Equation (1) asserts that only sequential production occurs for any producing field, so that a start-stop-start production sequence is disallowed. By this constraint, we have implicitly assumed that the economic cost of stopping and restarting a field in any period is prohibitive (see e.g. Abdul-Salam et al., 2021; Abdul-Salam et al., 2022). Binary variable $\alpha_{i,t}$ ultimately sequences the path to the optimal field economic limit, which is the point in the life of a field where cessation of production occurs due to the variables of the tax regime, the prevailing market price conditions, operating costs and so on.

Now for field i, let FS_i (million barrels of oil equivalent, mmboe) represent exogenous total 'field size' and let CE_i^{unit} (\$/mmboe) represent exogenous 'unit capital expenditure'. Also, let CE_i^{total} (\$ million; \$m) represent exogenous 'total capital expenditure'. Consequently, for any period t, per the new UK windfall taxation regime, the following statements on the accounting of tax allowances apply;

$$CE_i^{total} = CE_i^{unit} \cdot FS_i \; \forall \; i \tag{2}$$

$$CA_{i,t=1}^{total} = CE_i^{total} \cdot \alpha_{i,t=1} \tag{3}$$

$$scIA_{i,t=1}^{total} = scIA \cdot CE_i^{total} \cdot \alpha_{i,t=1} \tag{4}$$

$$wtIA_{i,t=1}^{total} = wtIA \cdot CE_i^{total} \cdot \alpha_{i,t=1} \tag{5}$$

$$CA_{i,t+1}^{total} = (1 + rfes) \cdot \left(CA_{i,t}^{total} - CA_{i,t}^{annual}\right) \; \forall \; i,t \tag{6}$$

$$scIA_{i,t+1}^{total} = scIA_{i,t}^{total} - scIA_{i,t}^{annual} \; \forall \; i,t \tag{7}$$

$$wtIA_{i,t+1}^{total} = wtIA_{i,t}^{total} - wtIA_{i,t}^{annual} \; \forall \; i,t \tag{8}$$

$$CA_{i,t}^{annual} \leq CA_{i,t}^{total} \; \forall \; i,t \tag{9}$$

$$scIA_{i,t}^{annual} \leq scIA_{i,t}^{total} \; \forall \; i,t \tag{10}$$

$$wtIA_{i,t}^{annual} \leq wtIA_{i,t}^{total} \; \forall \; i,t \tag{11}$$

where

Endogenous variables	Description
$CA_{i,t}^{total}$	Total capital allowance ($m)
$scIA_{i,t}^{total}$	Total investment allowance for relief against supplementary charge ($m)
$wtIA_{i,t}^{total}$	Total investment allowance for relief against windfall tax ($m)
$CA_{i,t}^{annual}$	Capital allowance applied annually for relief against all taxes ($m)
$scIA_{i,t}^{annual}$	Investment allowance applied annually for tax relief against supplementary charge ($m)
$wtIA_{i,t}^{annual}$	Investment allowance applied annually for tax relief against windfall tax ($m)
Exogenous parameters	**Description**
$scIA$	Investment allowance rate for tax relief against supplementary charge (%)
$wtIA$	Investment allowance rate for tax relief against windfall tax (%)
$rfes$	Ring Fence Expenditure Supplement (%)

Equation (2) determines the total capital expenditure of a field. This is expenditure incurred in field development, and includes drilling and completion expenditures of production and completion wells as well as the expenditures accompanying the installation of associated infrastructure (e.g. pipelines, manifolds, processing hubs, etc.). Equations (3) – (5) determine the total capital and investment allowances awarded by the UK Government to the field operator in the first year. These allowances are only incurred if field development and production is endogenously determined to occur, as shown in the accounting of the binary variable $\alpha_{i,t}$. Equations (6) – (8) capture the updating of the total allowance levels in subsequent periods, which involves deductions of the operator's endogenous annual allowance allocations for tax relief purposes. The Ring Fence Expenditure Supplement is used to supplement the intertemporal amount of capital allowances for purposes of maintaining the time value of money, as shown in Equation (6). Equations (9) – (11) ensure that the endogenous annual capital and investment allowances applied for tax relief purposes do not exceed the total available for any period.

2.1.2 Equations defining cashflows

Now let $x_{i,t}^{oil}$ (million barrels; mmbbl), $x_{i,t}^{cndnst}$ (million barrels; mmbbl) and $x_{i,t}^{gas}$ (million standard cubic feet; mmscf) represent exogenous oil, condensate and gas production profiles respectively. All operators for the twelve wholly new fields under consideration provide pre-determined oil, condensate and gas production profiles for the fields. These can be found in the EIA reports of the fields, as submitted by the operators to the UK Government, and as published on the UK Government website (see UK Government, 2022.g; UK Government, 2022.h). Consequently, the following equations outline definitions and constraints capturing the income statement of field i in period t, taking into account the capital and investment allowances determined above;

$$R_{i,t} = \left(P_t^{oil} \cdot x_{i,t}^{oil} + P_t^{cndnst} \cdot x_{i,t}^{cndnst} + P_t^{gas} \cdot \gamma \cdot x_{i,t}^{gas}\right) \cdot \alpha_{i,t} \ \forall \ i, t \tag{12}$$

$$PTP_{i,t} = \left(R_{i,t} - O_i\right) \cdot \alpha_{i,t} \ \forall \ i, t \tag{13}$$

$$TI_{i,t}^{total} = PTP_{i,t} - CA_{i,t}^{annual} \ \forall \ i, t \tag{14}$$

$$TI_{i,t}^{rfct} = TI_{i,t}^{total} \ \forall \ i, t \tag{15}$$

$$TI_{i,t}^{sc} = TI_{i,t}^{total} - scIA_{i,t}^{annual} \ \forall \ i, t \tag{16}$$

$$TI_{i,t}^{wt} = TI_{i,t}^{total} - wtIA_{i,t}^{annual} \ \forall \ i, t \tag{17}$$

$$tax_{i,t} = \max\left[0, rfct \cdot TI_{i,t}^{rfct} + sc \cdot TI_{i,t}^{sc} + wt \cdot TI_{i,t}^{wt}\right] \ \forall \ i, t \tag{18}$$

$$NCF_{i,t} = PTP_{i,t} - tax_{i,t} \ \forall \ i, t \tag{19}$$

where

Endogenous variables	Description
$R_{i,t}$	Total revenues ($m)
$PTP_{i,t}$	Pre-tax profit ($m)
$TI_{i,t}^{total}$	Total taxable income ($m)
$TI_{i,t}^{rfct}$	Taxable income for Ring Fence Corporation Tax ($m)
$TI_{i,t}^{sc}$	Taxable income for Supplementary Charge ($m)
$TI_{i,t}^{wt}$	Taxable income for Windfall Tax ($m)

$tax_{i,t}$	Tax paid ($m)
$NCF_{i,t}$	Net cashflow ($m)
Exogenous parameters	**Description**
P_t^{oil}	Price of oil ($/bbl; real)
P_t^{cndnst}	Price of condensate ($/bbl; real)
P_t^{gas}	Price of gas ($/mmbtu; real)
γ	Conversion factor of gas price from $/mmbtu to $/scf
O_i	Operating expenditure ($m)
$rfct$	Ring fence corporation tax rate (%)
sc	Supplementary charge rate (%)
wt	Windfall tax rate (%)

Equation (12) defines annual field revenues which are a function of the production volumes and prices of oil, condensate and gas. Equation (13) defines pre-tax profits, which include deduction of operating expenditures. We assume average operating expenditures which are non-variant over time, consistent with the cost structures of petroleum operations in the UKCS province (Abdul-Salam et al., 2021; Abdul-Salam et al., 2022). Equation (14) defines the total taxable income, which involves deduction of endogenously allocated capital allowances to provide the first-level of tax reliefs. Equation (15) defines taxable income for Ring Fence Corporation Tax (RFCT). Equation (16) defines taxable income for Supplementary Charge (SC), which involves further deduction of endogenously allocated supplementary charge investment allowances to provide second-level tax reliefs. Similarly, equation (17) defines taxable income for the Windfall Tax (WT), which involves further deduction of endogenously allocated windfall tax investment allowances to provide additional tax reliefs. Minimum tax paid in each period is 0, but maximum is levied as shown in equation (18). Equation (19) captures the net cashflows for each operational period of a field.

2.1.3   Objective function – NPV and DPI index

For each field i, the objective is to maximise the NPV as follows;

$$\text{maximise} \quad NPV_i = -CE_i^{total} \cdot \alpha_{i,t=1} + \sum_t \frac{NCF_{i,t}}{(1+r)^{t-1}} \tag{20}$$

where r is the discount rate. A project is deemed to be economically viable when the NPV is positive (OGA, 2016; OGA, 2018; Brealey and Myers, 2011). However, UKCS operators may not wish to invest in every NPV-positive project due to capital rationing considerations (OGA, 2018; Osmundsen et al., 2022). The DPI index is a more stringent SECR measure for project qualification and selection for development. For field i, the DPI index is simply a ratio of the NPV and the total capital expenditure, as follows;

$$DPI_i = \frac{NPV_i}{CE_i^{total}} \tag{21}$$

An NPV-positive hence economically viable field qualifies for development when the DPI index is 0.3 or higher (OGA, 2018). The solution to equation (20) accounts for the constraints and definitions in equations (1) – (19), as well as some further provisions, constraints and definitions reflecting the reality of petroleum field operations and taxation in the UKCS. For example, we impose constraints to prevent implicit subsidies by way of inappropriate allocations of capital and/or investment allowances for tax relief purposes. Our model also captures longstanding loss-carry-forward provisions in the UK taxation regime. To preserve space however, such further provisions, constraints and definitions are not presented here.

2.2   Model implementation

The above model is formulated in the General Algebraic Modelling System (GAMS) software and language as a Mixed Integer Non-Linear Programming (MINLP) problem. The model is solved using the LINDOGLOBAL solver in GAMS which ensures globally optimal solutions are obtained.

3   Data

Table 1 provides the metadata for all twelve fields, showing operator ownership and equity stakes, field location in the UKCS and projected first oil and/or gas date. For ease of modelling, we assume whole-year operations only. As such, fields that are projected to strike first oil or gas in the latter part of a year are assumed to do so at year beginning only (i.e. January). For field Rosebank, we assume an aggressively accelerated development drive to achieve an earlier

than planned first oil date in order for the field to benefit from the additional investment allowances available under the new windfall taxation regime.

Table 1: Metadata for all twelve new fields in the UKCS (Source: UK Government, 2022.g; UK Government, 2022.h).

| Field	Owners and ownership stakes	Projected first oil/gas date	Author assumed first oil/gas date	Location/Region
Abigail P50	Ithaca Energy (UK) Limited (80%); Ithaca Energy Developments UK Limited (20%)	Q3/4 2022	January 2023	Central North Sea; Block 29/10; approximately 233km east of Peterhead and 36km from the UK-Norway median line
Affleck	NEO Energy Production UK Limited (100%)	Q2 2024	January 2024	Central North Sea; Blocks 30/19a
Alwyn East	TotalEnergies Exploration and Production UK Ltd (100%)	September 2022	January 2023	Northern North Sea; Blocks 3/04b, 3/04g and 3/05a
Cambo	Siccar Point Energy Exploration and Production Ltd (70%); Shell UK Ltd (30%)	2025	January 2025	West of Shetland; Blocks 204/4a, 204/5a, 204/9a and 204/10a
Jackdaw P50	Shell UK Limited (via BG International Ltd) (74%) and One-Dyas E&P Ltd (26%)	Q3/Q4 2024	January 2024	Central North Sea; Blocks 30/02a, 30/03a DEEP, and 30/02d
Murlach	BP Exploration Operating Company Limited (BPEOC; 80%) and NEO Energy Central North Sea Limited (20%)	Q2 2025	January 2025	Central North Sea; Block 22/24h
Pegasus West	Spirit Energy Resources Limited, Spirit Energy North Sea Limited and Neptune E and P UK Limited. Various ownership structures	Q1-Q3 2024	January 2024	Southern North Sea; Blocks 43/13b, 43/14, 43/15, 44/11 and 44/12
Rosebank	Equinor UK Ltd (40%); Suncor Energy UK Ltd (40%); Ithaca SP E&P Limited (20%)	Q4 2026	January 2025	West of Shetland; 130 km north-west of Shetland; Blocks 213/26b, 213/27a, 205/1a, 205/2a
Talbot	Harbour Energy Plc and Eni UK Ltd	Q3 2024	January 2024	Central North Sea; Block 30/13e under Licence P.2456; 278km Southeast of Peterhead
Teal West	Anasuria Hibiscus UK Ltd (70%); Neo Energy Production UK Ltd (30%)	Q2 2024	January 2024	Central North Sea; Block 21/24d
Tolmount East	Premier Oil UK Ltd (50%) and Dana Petroleum E & P Ltd (50%)	August 2023	January 2023	Southern North Sea; Block 42/28d
Victory	Corallian Energy Limited (100%)	Q4 2024	January 2024	West of Shetland; Block 207/01a, approximately 47 km northwest of the Shetland Islands

3.1 Production profiles

We use the oil, condensate and gas production profile data for all twelve fields, as provided in the field EIA reports published by the UK Government (see UK Government, 2022.g; UK Government, 2022.h). These profiles are shown in Figure *2*. As previously indicated, we incorporate the field production profiles as exogenous to our model. The model however ultimately determines field economic limit endogenously, based on model variables on taxation, prevailing market conditions (e.g. oil and gas prices), operating costs, etc.

Figure 2: Actual projected production profiles of oil, gas and condensate for the twelve new fields in the UKCS (Source: Author plots using data obtained from UK Government, 2022.g and UK Government, 2022.h).
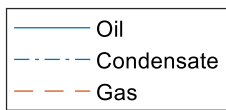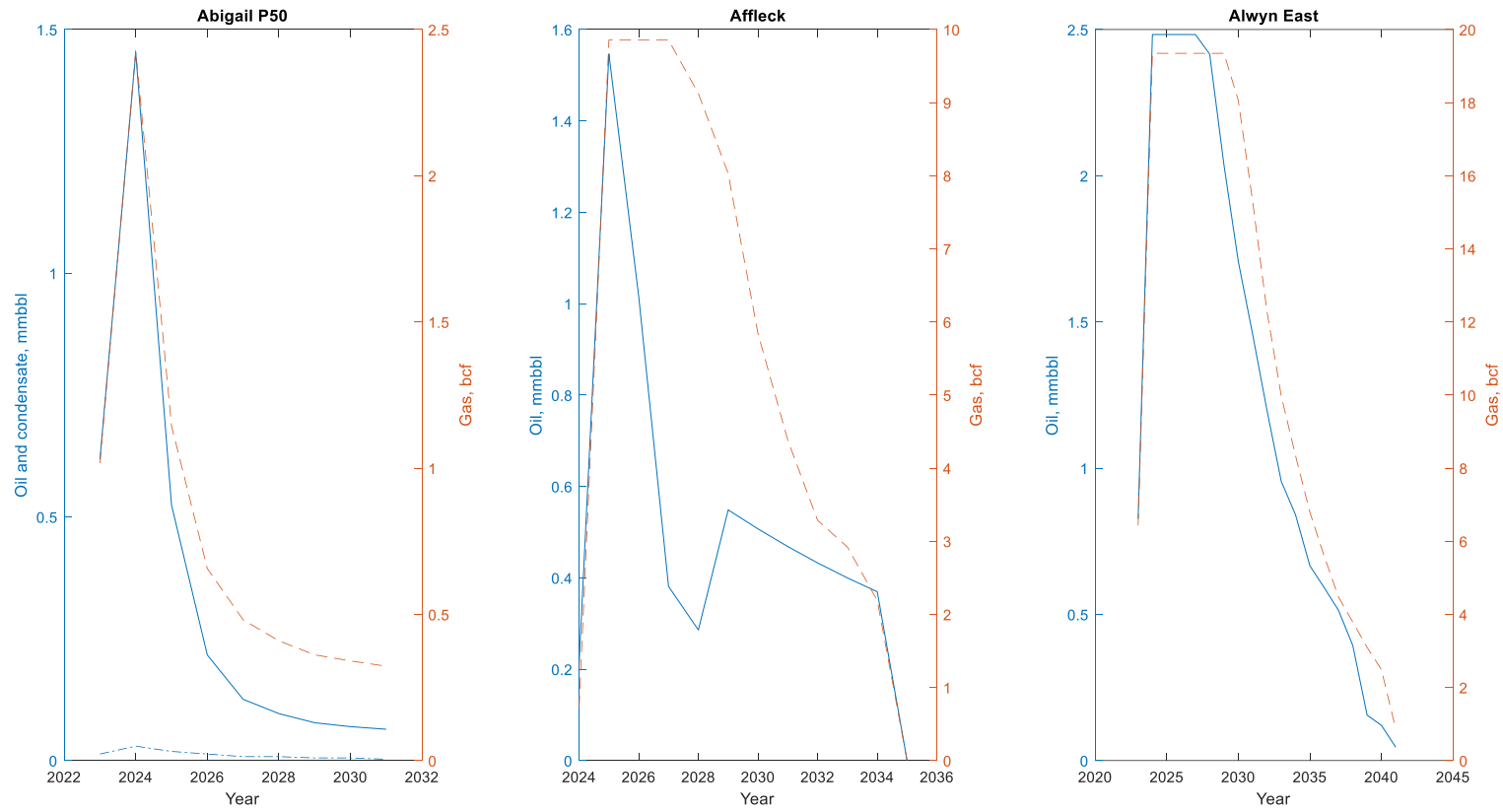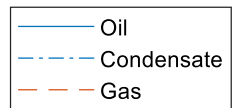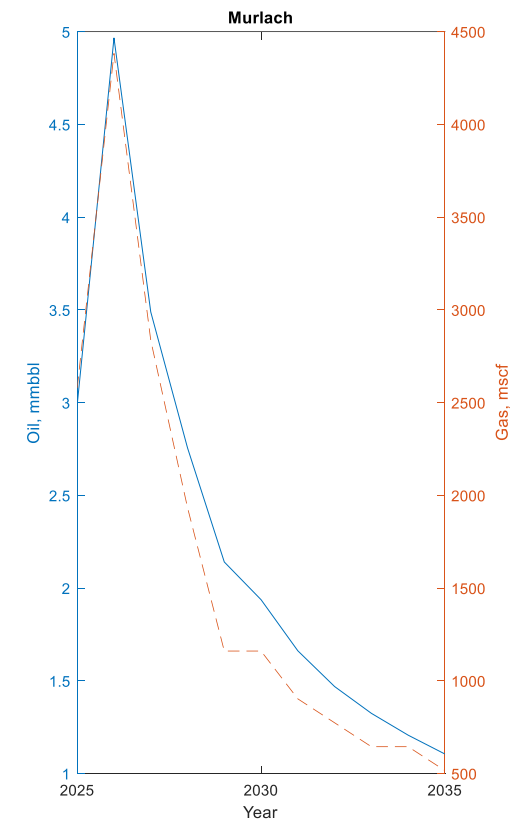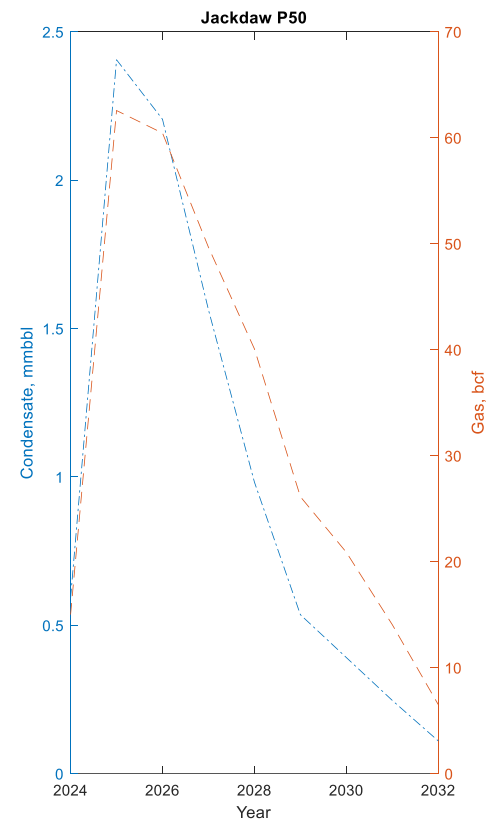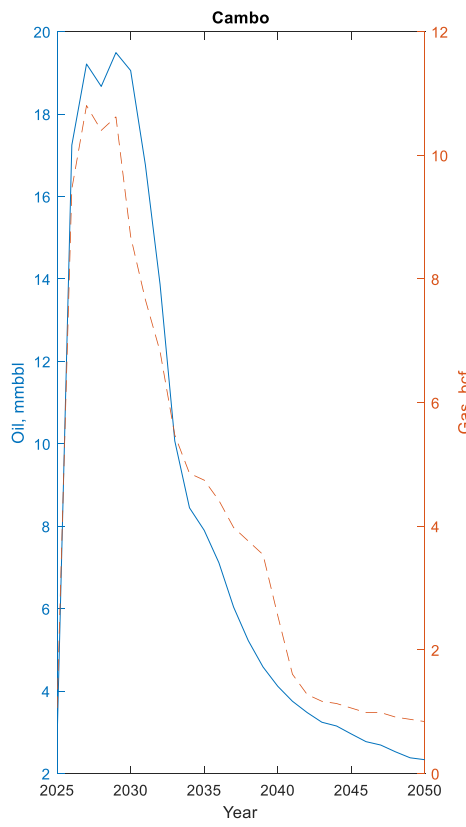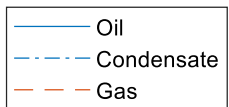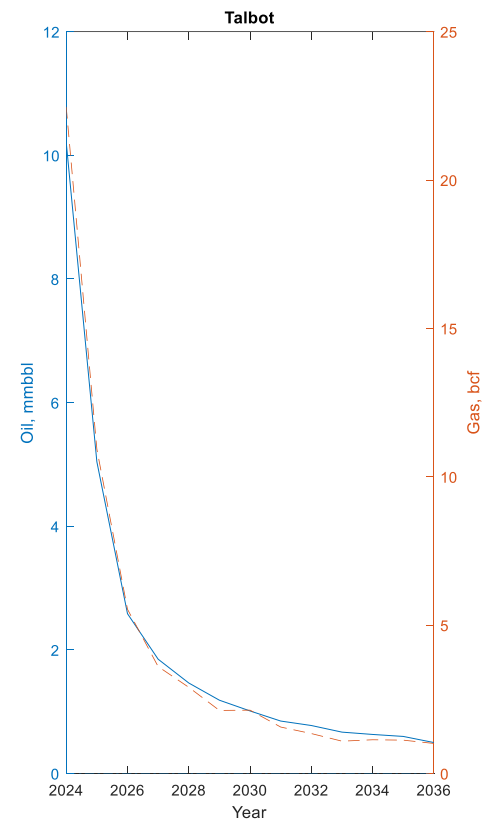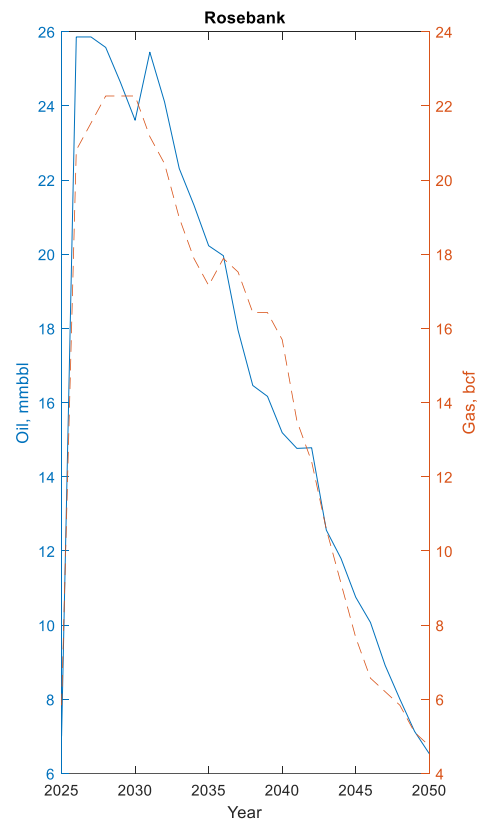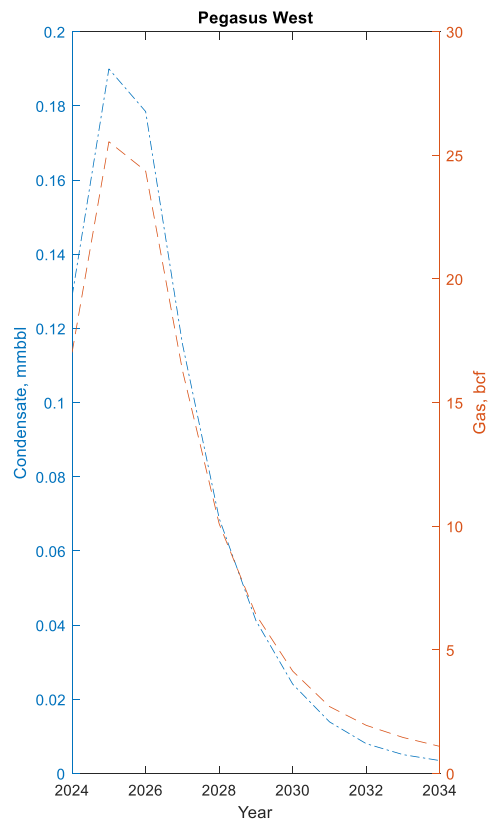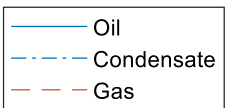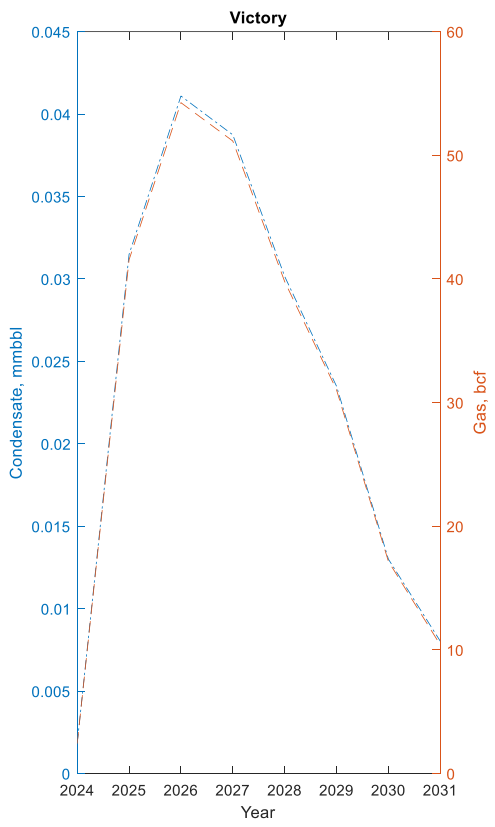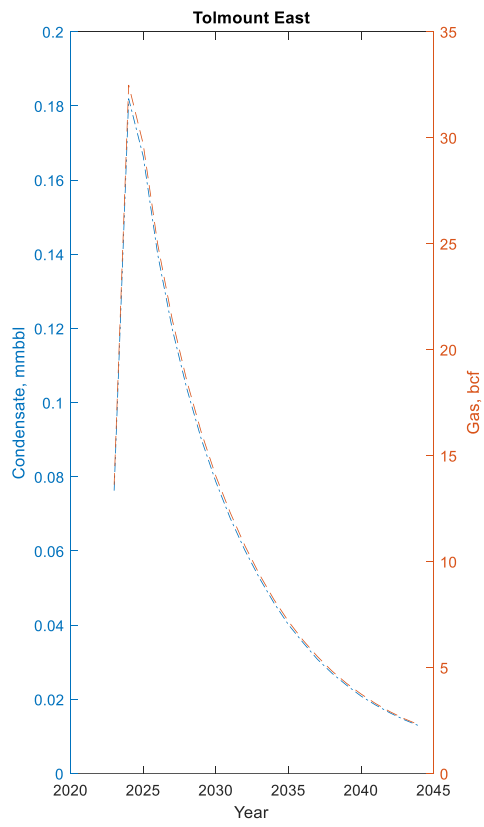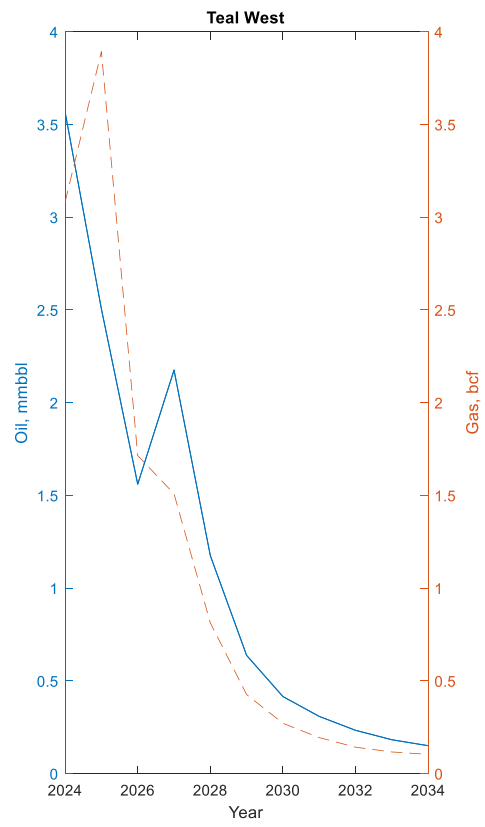
Table 2 provides the aggregate hydrocarbon reserve levels for each field. The Rosebank field in the West of Shetland is the biggest field, with about 47.63% of the total hydrocarbon reserves across the fields. It also has the biggest oil reserves and gas reserves. Jackdaw, Pegasus West, Tolmount East and Victory are predominantly gas fields, whereas Murlach is a predominantly oil field with a relatively small proportion of gas. A potential total of 1049.33 mmboe of oil, gas and condensate reserves may be realised across the twelve fields.

Table 2: Total reserve volumes of oil, condensate and gas in the 9 new UKCS fields (Source: UK Government, 2022.g; UK Government, 2022.h).

Field	Oil (mmbbl)	Gas (bscf)	Condensate (mmbbl)	Total hydrocarbons (mmboe)
Abigail P50	3.25	7.16	0.10	4.55
Affleck	6.17	66.07	-	17.20
Alwyn East	23.85	213.59	-	59.52
Cambo	209.90	109.68	-	228.22
Jackdaw P50	-	295.21	9.03	58.33
Murlach	25.04	0.02	-	25.05
Pegasus West	-	111.10	0.78	19.33
Rosebank	436.98	376.32	-	499.83
Talbot	27.37	56.96	-	36.89
Teal West	12.90	12.26	-	14.95
Tolmount East	-	254.44	1.42	43.92
Victory	-	247.73	0.19	41.56
Total	745.47	1,750.52	11.52	1,049.33

* bscf is billion standard cubic feet of gas

3.2 Expenditure data

We do not have access to commercially sensitive capital and operating expenditure data for the twelve new fields under consideration. Following Abdul-Salam et al. (2021) therefore, we use data on the average unit capital expenditures of fields in the UKCS to calculate the total capital expenditure of each field. The field EIA reports show that many of the fields are to be tied into existing infrastructure hence reducing their unit capital expenditures considerably. For this reason, we choose the unit capital expenditures at the lower end of the spectrum for each region of the UKCS as follows; Southern North Sea ($6.58/bbl), Central North Sea ($5.71/bbl), Northern North Sea ($6.86/bbl), West of Shetland ($7.94/bbl) (see Abdul-Salam et al., 2021). Total capital expenditure is calculated as the product of the unit capital expenditure and field size, as shown in equation (2). Finally following Abdul-Salam et al. (2021), Abdul-Salam (2022) and OGA (2018), we assume that the annual operating expenditure of each field is up to 10% of the field capital expenditure.

3.3 Other data

Table *3* summarises other model data including the parameters of the new UK windfall taxation regime for petroleum operations in the UKCS. The key changes to the previous taxation regime are the introduction of the windfall tax of 35% and the super-deduction style investment allowance of 29% for windfall tax relief, as previously discussed.

Table 3: Other model data.

Parameter	Base values		Sensitivity values	Source/Comment
Taxation	**Tax rates**			
	Windfall tax, %	35	-	UK Government, 2022.a
	Ring Fence Corporation Tax, %	30	-	UK Government, 2022.a; UK Government, 2022.b
	Supplementary Charge, %	10	-	UK Government, 2022.a; UK Government, 2022.c
	Tax allowance rates			
	Super-deduction Investment Allowance for Windfall Tax, %	29	-	UK Government, 2022.a
	Investment Allowance for Supplementary Charge, %	62.50	-	UK Government, 2022.a; UK Government, 2022.d
	Capital Allowance, %	100	-	UK Government, 2022.a; UK Government, 2022.e
	Ring Fence Expenditure Supplement, %	10	-	UK Government, 2022.a; UK Government, 2022.f
Prices	Oil price ($/bbl, real)	70	Min: 0; Max:100	Within range of US EIA (2021.a) short term Brent crude price forecast and the UK OBR (2022) estimates
	Condensate price ($/bbl, real)	70	Min: 0; Max:100	Within range of US EIA (2021.a) short term Brent crude price forecast and the UK OBR (2022) estimates
	Gas price ($/mmbtu, real)	4	Min: 0; Max:8	BP (2021), based on the Heren NBP natural gas price index.
Other	Discount rate (real)	10	-	OGA, 2018; Abdul-Salam et al., 2021; Abdul-Salam et al., 2022
	Conversion factor (Gas mmscf to mmboe)	1.67e-4	-	BP, 2022; US EIA, 2021

4 Results

4.1 Economic Value: NPV and DPI index

Figure *3* shows the effect of the new windfall taxation regime on field economic values using the NPV metric. The results show a varied effect of the windfall taxation system on the twelve wholly new UKCS fields, relative to the previous taxation regime. All fields show reductions in field economic value. The Talbot field shows the highest quantum reduction of about $318.19 million; whilst field Abigail P50 shows the highest percentage reduction of about 53.11%. Both fields are majorly affected by the tax due to their projected exponential rate of production and depletion within the term of the tax (see Talbot and Abigail P50 production profiles in Figure *2*). Some fields show only marginal reductions in field economic values, indicating resilience and/or minimal exposure to the windfall tax. Fields Rosebank and Cambo for example show only 8.21% and 11.50% reductions respectively. Both fields begin production in 2025, exposing them to only two and a quarter years of the windfall tax and affecting only a small fraction of their cumulative projected lifetime production volumes (see Cambo and Rosebank production profiles in Figure *2*). They also have enough of the new 29% super-deduction investment allowance to substantially shield from payment of the windfall tax in that period.
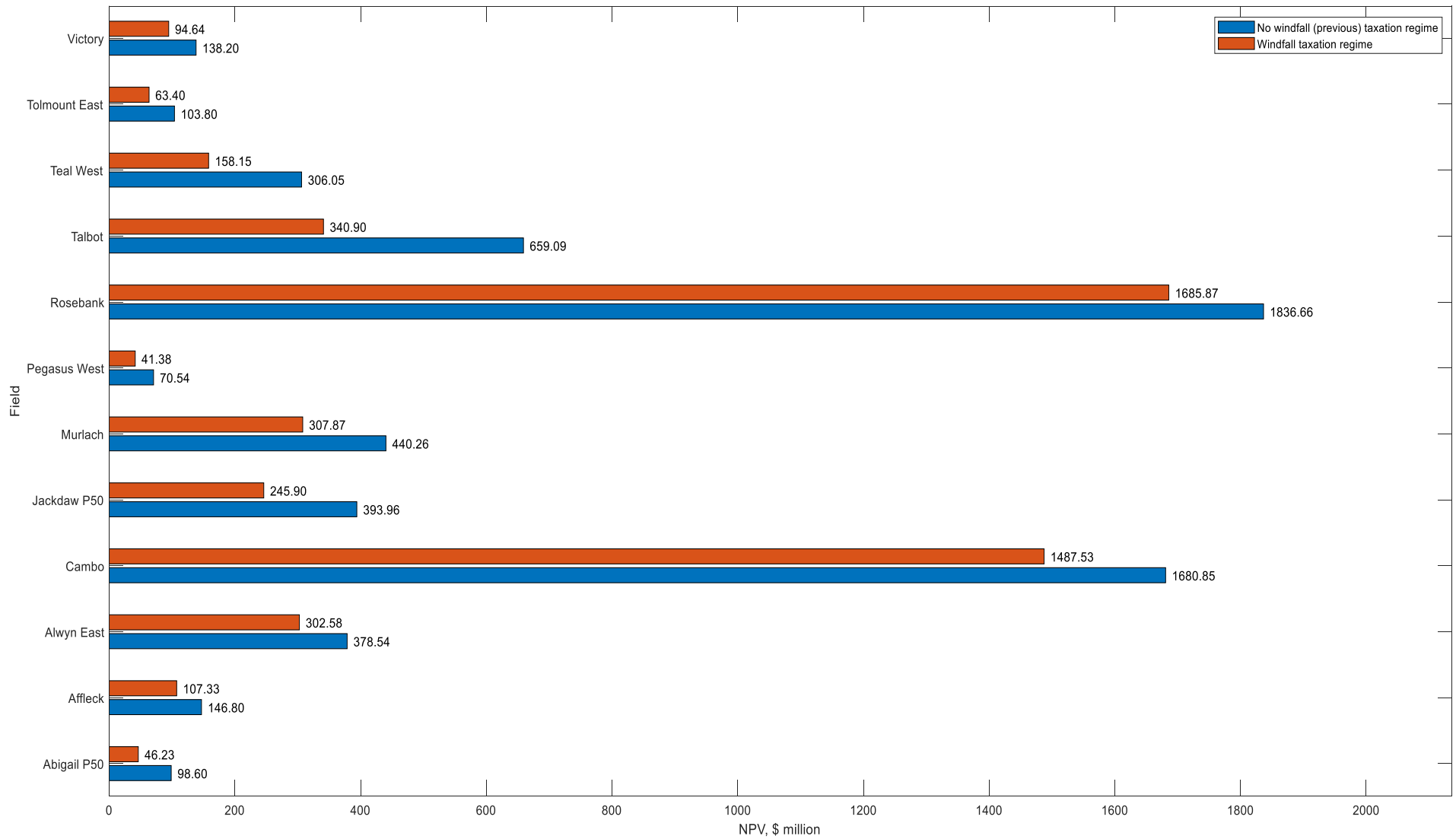
Figure 3: Effects of the new windfall taxation regime on field economic values.

As previously indicated, the DPI index is a more stringent metric for project qualification and selection for development. Figure *4* shows the effect of the new windfall tax on the index. The results show that eleven of the twelve wholly new UKCS fields under consideration have DPI index values above 0.3, the required minimum for qualification and selection, in both the previous taxation regime and the new windfall taxation regime. This shows that the windfall tax is unlikely to cause abandonment of most of the new UKCS fields currently under review by the UK Government for EIA approval. Given the significant swing in DPI index values for some fields however (see e.g. Abigail P50, Teal West and Talbot), it is foreseeable that the windfall tax can cause an abandonment of marginal UKCS fields with index values around the required 0.3 threshold mark. This is indeed the case for field Tolmount East. The DPI index of the field drops below the threshold mark of 0.3 after the imposition of the windfall tax hence causing the field to be ineligible for development under this metric.
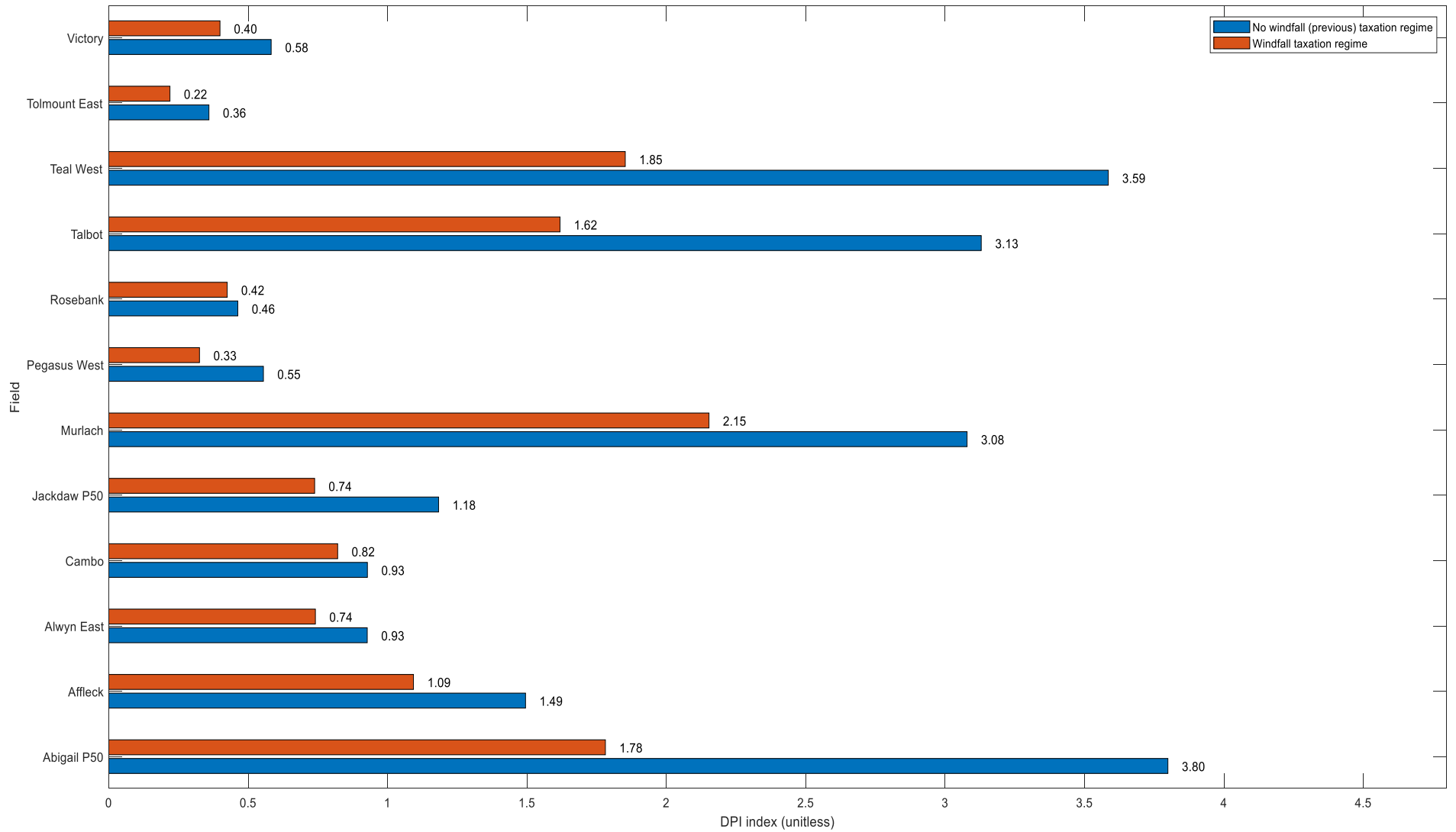
Figure 4 : Effects of the new windfall taxation regime on field DPI index for project qualification and selection for development.

4.2   Effect of new investment allowance

Table 4 shows the effect of the 29% super-deduction investment allowance introduced as part of the new windfall taxation regime for enhanced tax reliefs. To highlight this effect, we contrast the result of the imposition of the windfall tax with and without the allowance. The result shows that the new investment allowance provides significant protection against the value-reducing effect of the windfall tax. Up to 26.02% of the value of field Tolmount East for example is preserved due to the tax-shielding effect of the investment allowance. For fields Cambo and Rosebank, more than $100 million in value is preserved. Overall, a total of $393.67 million in field value is preserved across the twelve new fields as a result of the provision of the super-deduction investment allowance in the windfall taxation regime.

The effect is also observed in the DPI index results in Table 4. These results show, as expected, that the provision of the 29% super-deduction investment allowance enhances the DPI index values of fields hence improving their suitability for selection for development. The extent of the enhancement is such that for most fields, suitability for development is unaffected with or without the investment allowance. For marginal fields such as Tolmount East and Pegasus West however, the investment allowance may be consequential in determining qualification and selection for development. Without the new investment allowance, Pegasus West ceases to be economically viable with a DPI index value of 0.27 only.

Table 4: Effects of the introduction of the new 29% super-deduction investment allowance in the windfall taxation regime.

Field	NPV, $ million				DPI index (unitless)			
	With new 29% IA	Without new IA	ΔNPV	%ΔNPV	With new 29% IA	Without new IA	ΔDPI index	%ΔDPI index
Abigail P50	46.23	43.84	2.40	5.32	1.78	1.69	0.09	5.32
Affleck	107.33	99.63	7.70	7.44	1.09	1.01	0.08	7.44
Alwyn East	302.58	274.79	27.80	9.63	0.74	0.67	0.07	9.63
Cambo	1,487.53	1,386.75	100.78	7.01	0.82	0.77	0.06	7.01
Jackdaw P50	245.90	218.67	27.23	11.72	0.74	0.66	0.08	11.72
Murlach	307.87	296.97	10.91	3.61	2.15	2.08	0.08	3.61
Pegasus West	41.38	34.08	7.30	19.34	0.33	0.27	0.06	19.34
Rosebank	1,685.87	1,526.77	159.10	9.90	0.42	0.38	0.04	9.90
Talbot	340.90	323.23	17.67	5.32	1.62	1.53	0.08	5.32
Teal West	158.15	150.99	7.16	4.63	1.85	1.77	0.08	4.63
Tolmount East	63.40	48.80	14.60	26.02	0.22	0.17	0.05	26.02
Victory	94.64	83.60	11.04	12.38	0.40	0.35	0.05	12.38
Total	4,881.79	4,488.12	393.67					

4.3 Tax-take for the UK Government Exchequer

Figure *5* shows the total tax-take by the UK Government Exchequer over the lifetime of the fields. We contrast the tax-take for the previous taxation regime with the new windfall taxation regime. Total tax under the previous regime is $12.26 billion. Under the windfall taxation regime however, this increases to $14.24 billion, a difference of about $1.97 billion. This difference constitutes the windfall tax gains to the UK Government Exchequer. The gain is attributable to the combined effect of the instruments of the new windfall taxation regime; namely the tax-take-enhancing 35% windfall tax and the tax-take-shielding 29% super-deduction investment allowance. Fields with higher exposure to the tax such as Abigail P50, Talbot and Teal West incur the highest percentage increases in tax under the windfall taxation regime. Field Talbot for example incurs the most increase in tax of about $418.80 million, representing a 64.15% tax hike, whilst Abigail P50 and Teal West have 78.76% and 67.51% tax hikes respectively.
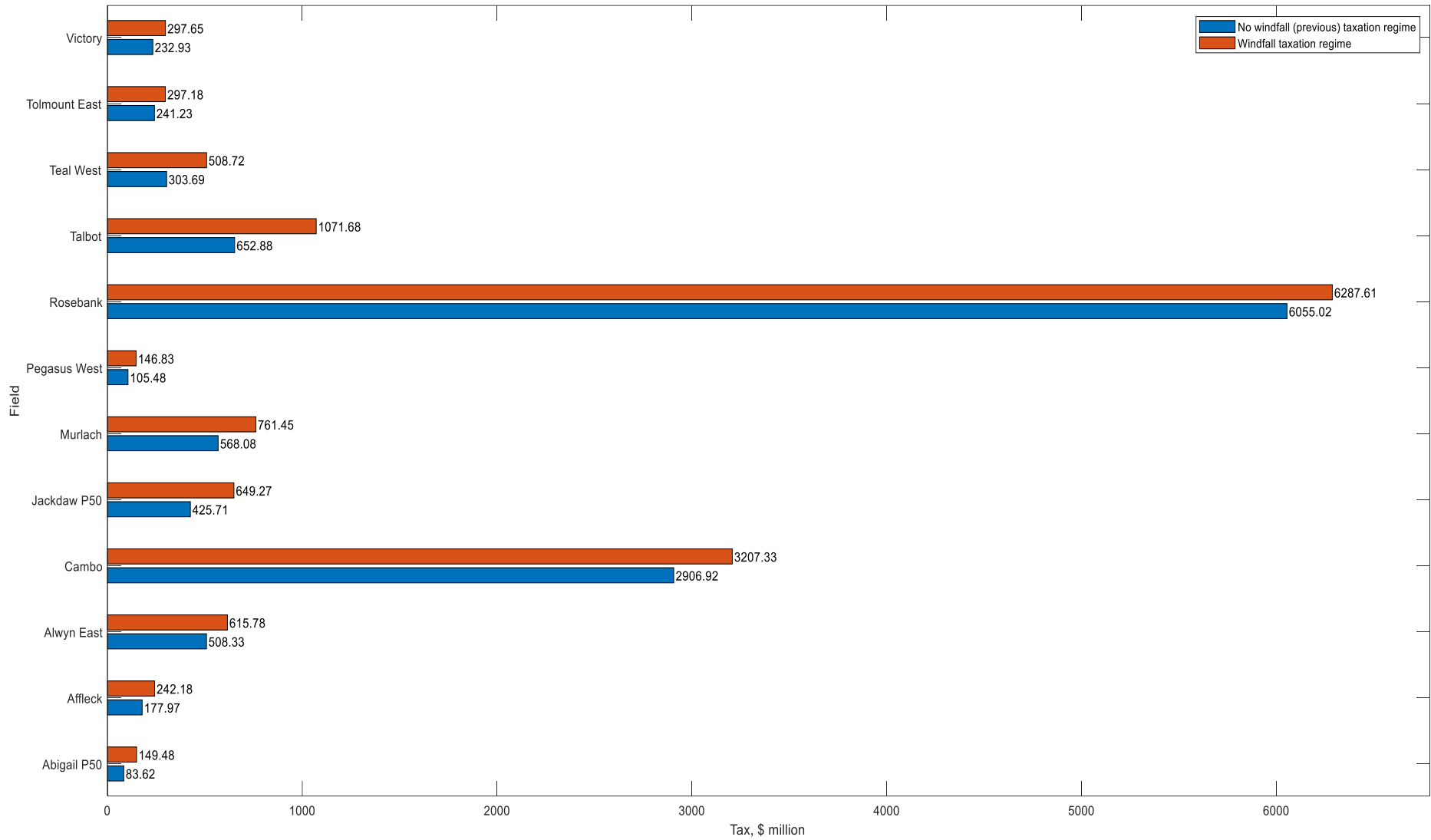
Figure 5: Effects of the new windfall taxation regime on UK Government Exchequer tax-take.

The aggregate windfall tax gain of about $1.97 billion to the UK Government Exchequer constitutes about 13.86% of the total tax-take of $14.24 billion under the windfall taxation regime. This is considerably lower than the 35% windfall tax rate. To explain this, note that the windfall tax is imposed for a maximum of only five and a quarter years and has a 29% super-deduction investment allowance tax shield. The corporation tax and the supplementary charge however are field lifetime annual taxes. They therefore contribute to the bulk of the total tax-take for the UK Government Exchequer.

4.4 Sensitivity analysis: Critical oil prices

The original UK government guidance underpinning the introduction of the windfall taxation regime in May 2022 stated that the tax would be phased out when oil and gas prices return to 'historically more normal levels'. The legislation however did not specify what these levels are hence introducing some level of uncertainty for the UKCS sector. In Figure *6*, we show for a given gas price the critical (i.e. minimum) oil price required for a DPI index value of 0.3 or higher needed for field qualification for development. We show this for eight of the twelve new fields with both oil and gas resource and production profiles. For a realistic gas price of about $3.00/mmbtu for example, the critical oil prices are $59.18/bbl for Alywn East, $55.10/bbl for Cambo, $38.78/bbl for Affleck, $67.35/bbl for Rosebank and $26.53/bbl for Talbot. Affleck and Alwyn East have a relatively high elastic critical oil price response to gas price levels. This is due to their relatively high levels of gas as a proportion of total field resource (i.e. 64.10% gas for Affleck and 59.90% gas for Alwyn East). Some fields however have relatively inelastic critical oil price responses to gas price levels due to their relatively lower levels of gas as a proportion of their total resource. These include Cambo, Rosebank and Murlach, each of which have less than 13% gas as a proportion of total field hydrocarbons.
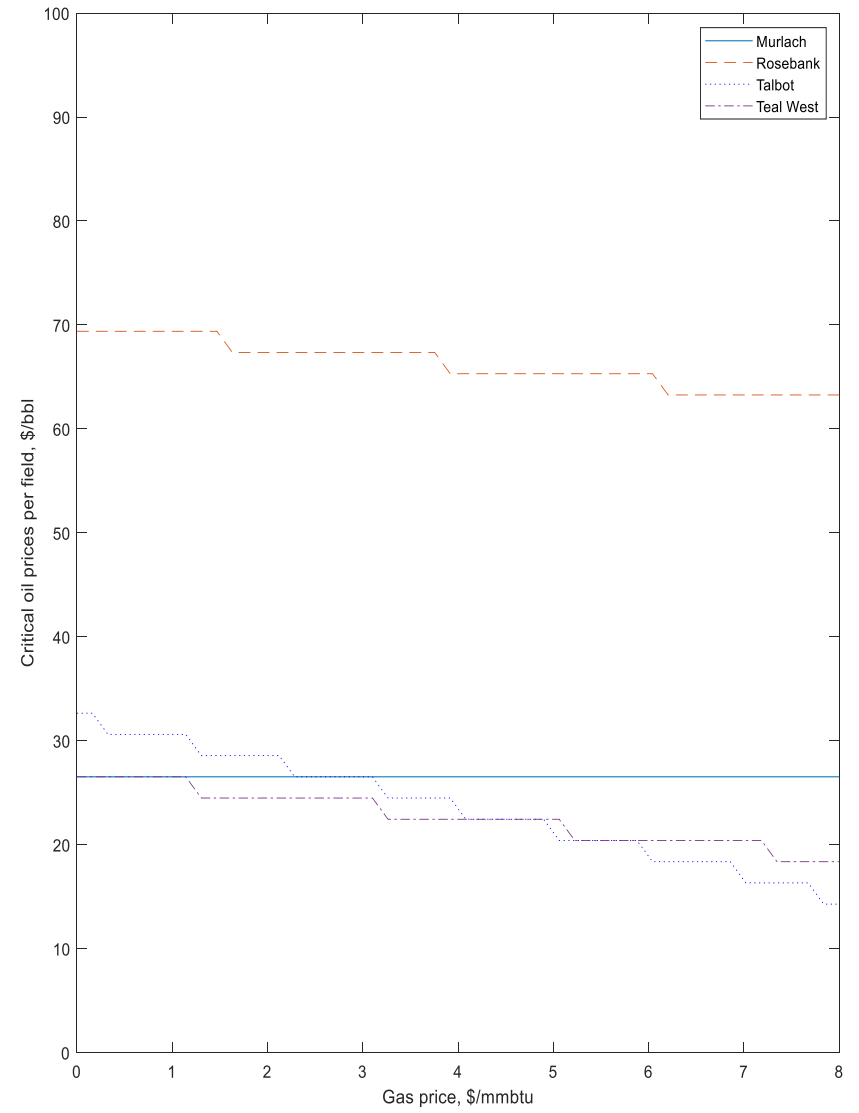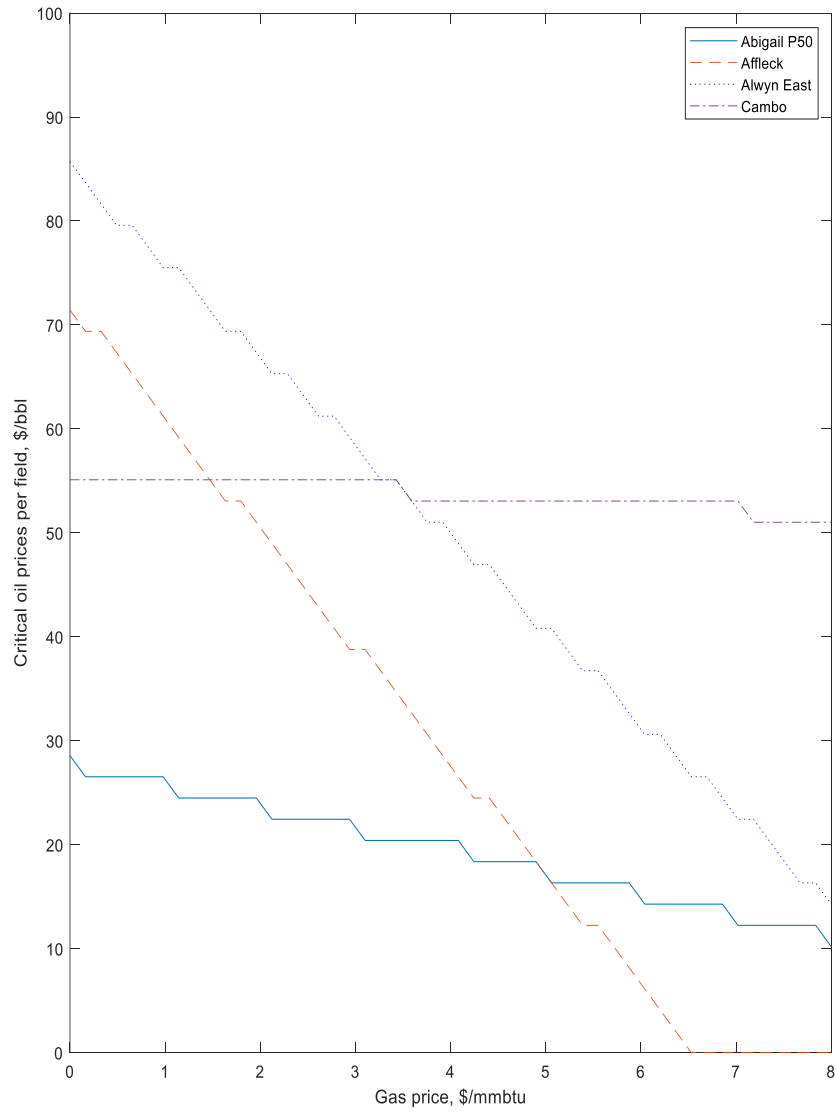
Figure 6: Critical oil prices for specific fields– Prices below which fields become un-economic.

The critical oil prices required for all fields to be eligible for development (i.e. have DPI index values of 0.3 or higher) for any gas price is derived in Figure 7. At a realistic average gas price of about $3.70/mmbtu for example,[9] a critical oil price of about $67.35/bbl is required for all fields to be economically viable. Critical oil prices range from about $85.71/bbl for a low gas price of $0.00/mmbtu to about $63.27/bbl for a high gas price of $8/mmbtu. The critical oil price profile derived here may be used by the UK Government to guide decisions on the timing of the phase out of the windfall taxation regime.

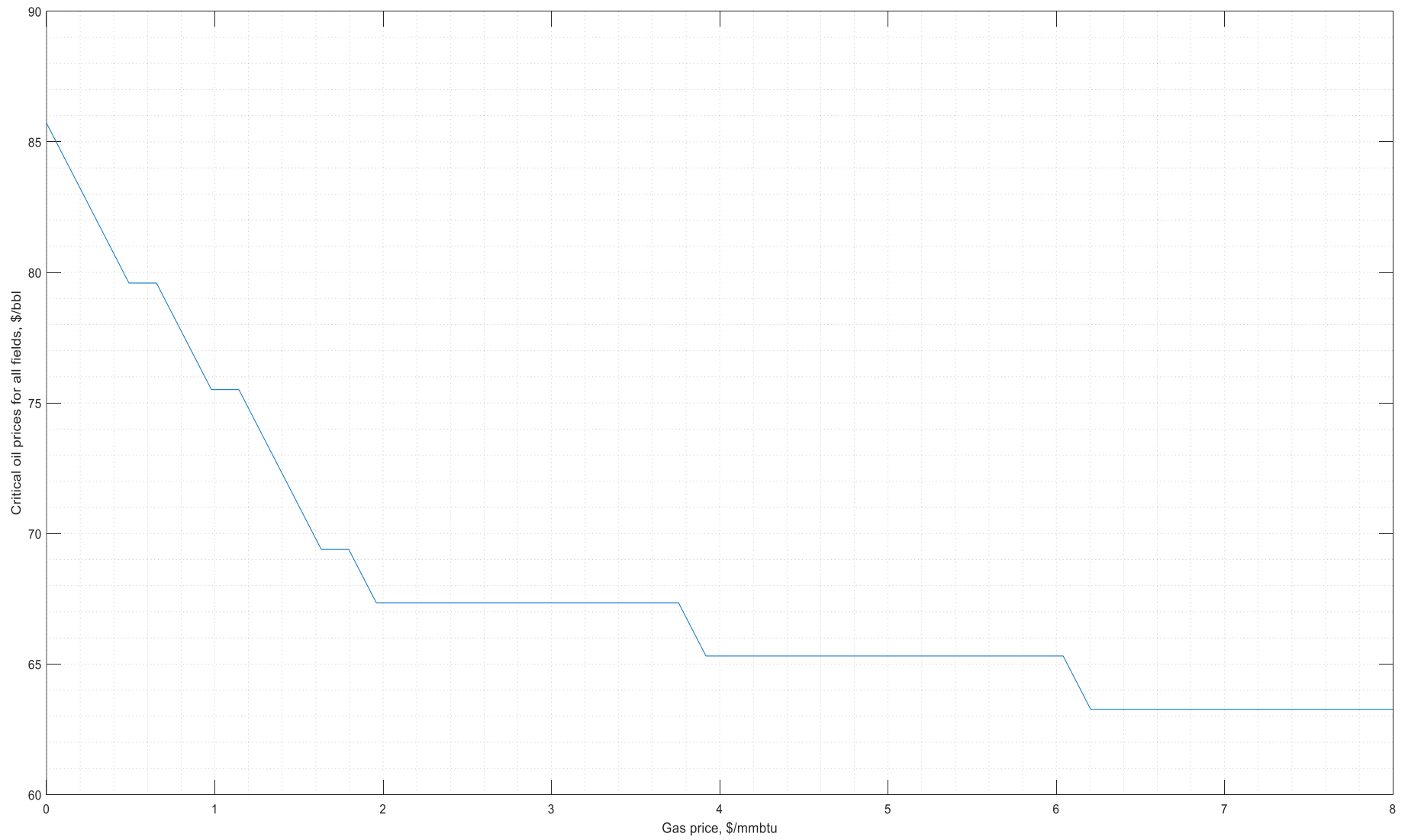[9] The average gas price from January 2020 to July 2022 is about $3.71/mmbtu (see EIA, 2022)

Figure 7: Critical oil prices for all new fields to be economically viable.

5 Conclusion and Policy Implications

Global politico-economics have led to record-high increases and levels in the prices of oil and gas and their derivative and associated products. In the UK, this has led to a cost-of-living crisis with record-high inflation levels eroding the real incomes of households. Meanwhile the increase in the prices of oil and gas has meant that the upstream UKCS sector is making significant profits, with the net rate of return of UKCS companies increasing significantly over the past two years. To help fund a cost-of-living support scheme for UK households, the UK Government introduced a windfall tax on upstream UKCS operations. This constitutes a major change in the fiscal regime of the upstream UKCS sector. There have been concerns by industry stakeholders that the newly introduced tax would downgrade the value of UKCS fields hence diminishing the global competitiveness of the province and dampening investor appetite to invest in the sector. In this paper, we examined the impact of the new taxation regime on twelve wholly new fields in the province, and on UK Government tax revenues.

Our results show that whilst the windfall tax reduces the economic value of all fields, as measured by the NPV metric, the magnitude of the reduction is insufficient to cause any of the fields to be uneconomic. This finding, to a significant extent, also holds when a more stringent SECR metric for field qualification for development, i.e. the DPI index, is used. The UK windfall tax therefore more generally is unlikely to cause premature abandonment of sufficiently prolific new fields, and by extension existing and ongoing operations in the sector. It is hence reasonable to project from our results that the introduction of the tax would not irredeemably injure the global competitiveness of the province and that existing companies are unlikely to exit from the sector as is the concern of some industry stakeholders.

For the UK Government, the new windfall tax would raise about $1.97 billion from the twelve wholly new fields considered here. This however constitutes about 13.86% of the total tax raised from the fields.

The original legislation underpinning the windfall taxation regime indicates that the windfall tax would be phased out when oil and gas prices return to historically more normal levels. As these levels have not been specified by the UK Government, an element of uncertainty has been introduced into the sector. In our analysis we show the critical oil price levels needed for the oil and gas fields in question to meet the DPI index threshold of 0.3 or higher required to qualify for development. For a recently observed gas price average of about $3.70/mmbtu for example, the critical oil price required for all fields to meet the DPI index threshold under the

new windfall taxation regime is about $67.35/bbl. Oil prices below this level would cause some fields to be economically unviable. Our analysis on critical oil prices may be used by the UK Government as a policy guide to trigger an accelerated phase out of the windfall tax in order to maintain the global competitiveness of the UKCS province.

In conclusion, the design of the new UK windfall taxation regime is unlikely to cause significant changes in the conduct of business in the UKCS province. This however only remains true when oil and gas prices are sufficiently high. The UK Government should monitor prices closely as price levels lower than the critical levels shown here, with the windfall taxation regime still in effect, may have consequentially negative implications for the global competitiveness of the UKCS province.

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