

# The effect of European fuel-tax cuts on the oil income of Russia

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Following Russia's invasion of Ukraine, there has been a surge in transport fuel prices. Consequently, many European Union (EU) countries are cutting taxes on petrol and diesel to shield consumers. Using standard theory and empirical estimates, here we assess how such tax cuts influence the oil income in Russia. We find that an EU-wide tax cut of €0.20 l<sup>-1</sup> increases Russia's oil profits by around €8 million per day in the short and long term. This is equivalent to €3,100 million per year, 0.2% of Russia's gross domestic product or 5% of its military spending. We show that a cash transfer to EU citizens—with a fiscal burden equivalent to the tax cut—reduces these side effects to a fraction.

Following Russia's military attack on Ukraine, the European Union (EU) and United States have imposed a large number of sanctions on Russia<sup>1,2</sup>. The attack has also led to a negative supply shock of oil, partly because Russia's ability to export has been hampered by the lack of will to insure Russian ships<sup>3</sup>, but also due to industry preparation for the upcoming EU oil import ban<sup>4</sup>. Together with surging post-pandemic demand, this has led to very high prices of transport fuels<sup>5,6</sup>. In response, a large number of European countries are either discussing or have already implemented a reduction in fuel taxes to help consumers cope with high prices. These include Austria, Belgium, France, Germany, Italy, the Netherlands, Romania and Sweden (see the Methods section 'Fuel price and taxes' and, for example, refs. 7–9 for details). Such tax reductions have problematic consequences since they increase demand, thus making current supply even more scarce. Some of the tax reduction will be attenuated by an increase in the underlying oil price, leading to increased profits for oil producers. Here, we assess the magnitude of this effect using basic theory and empirical estimates from the oil sector. We ask: 'How much does the oil income in Russia increase following fuel-tax reductions in the EU?' Knowing the answer to this question is highly relevant to policy as Russia's oil profits may undermine the geopolitical interests of the EU, reduce the effectiveness of the EU's sanctions and ultimately improve the ability of Russia to wage war.

Here, we show that an EU-wide fuel-tax cut equivalent to €0.20 l<sup>-1</sup> would increase Russia's oil profits by €36 million per day in the first month, €8.4 million per day during the rest of the first year and €8.2 million per day beyond the first year. The additional profits are equivalent to 0.2% of Russia's gross domestic product (GDP) and 5% of its defence

spending. The fiscal cost to the EU would be €170 million per day during the first year. An alternative policy with an equivalent fiscal cost is studied as well: providing EU citizens with cash transfers. Such a policy yields a fraction of the tax cut's profits to Russia and is ultimately more flexible for citizens as they can use the cash on anything they please.

## Theoretical approach

Here, we describe how we derive the effects of a decreased fuel tax in the EU on Russian oil profits. Our analysis uses a standard model of supply and demand for oil. Our approach is similar to those of Erickson and Lazarus<sup>10</sup> and Faehn et al.<sup>11</sup>. To analyse the effects of the EU's tax, we distinguish between oil demand for road transport fuels in the EU and remaining global oil demand. Similarly, to focus on the effects on Russian revenues, we distinguish between oil supply from Russia and supply from the rest of the world. We also consider the alternative policy of income transfers to households.

The first step is to derive how the global oil market responds to changes in the EU's road transport fuel tax. More detailed derivations are provided in the Methods. The global per-unit crude oil price is denoted  $p$ . To make the crude oil usable as fuel for end users, it must be refined, transported and so on. For the EU, we assume a per-unit cost  $c$  for this (in the Methods, we consider analytically the case where these costs are instead proportional to the oil price, and assess this case quantitatively in Supplementary Note 3). Additionally, road fuel users in the EU pay a fuel excise tax  $\tau$  per unit of fuel, as well as the value-added tax (VAT) rate  $\nu_{EU}$ . The market equilibrium is found by equating the demand for crude oil for road transport in the EU,

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$D_{EU}((1 + \nu_{EU})(p + c + \tau))$  (in many EU countries, VAT also applies to the excise tax; hence,  $(1 + \nu_{EU})$  multiplies  $\tau$ ), and the remaining global demand for crude oil,  $D_{ROW}(p)$ , to the supply from Russia,  $S_{RU}(p)$ , and from the rest of the world,  $S_{ROW}(p)$ :

$$D_{EU}((1 + \nu_{EU})(p + c + \tau)) + D_{ROW}(p) = S_{RU}(p) + S_{ROW}(p) \quad (1)$$

Since our focus here is on tax cuts on transport fuel,  $D_{EU}$  should be understood as the demand for crude oil to be used as oil-based road transport fuel in the EU (that is, mainly petrol and diesel). With some abuse of technical differences, we will often refer to it only as fuel.  $D_{ROW}$  should be understood as the global demand for all other oil products except road fuel in the EU (that is, it also includes non-road oil products in the EU). We assume that the EU's crude demand depends on the fuel price, including costs and taxes, while we assume that rest of the world demand depends on the oil price.

The effect of a change in the tax on the equilibrium price can then be found by treating the price as a function of the tax, differentiating the equilibrium condition fully with respect to the tax, solving for the derivative of the price with respect to the tax and rewriting. Let  $x$  denote the share of global demand for oil that comes from road fuel demand in the EU and let  $y$  denote Russia's share of the global oil supply. The market response to a change in the tax depends on the supply and demand elasticities in the submarkets. Let  $\tilde{\epsilon}_{D,EU}$ ,  $\epsilon_{D,ROW}$ ,  $\epsilon_{S,RU}$  and  $\epsilon_{S,ROW}$  denote the demand elasticities in the EU and the rest of the world and the supply elasticities of Russia and the rest of the world, respectively. The demand elasticity for the EU measures the response in demanded quantities of oil to changes in the end user prices, including additional costs and taxes, while the other elasticities measure responses of quantities of oil to changes in the oil price. Using this notation, the effect of a tax change on the oil price is given by the derivative

$$\frac{dp}{d\tau} = \frac{x \frac{p}{p+c+\tau} \tilde{\epsilon}_{D,EU}}{y \epsilon_{S,RU} + (1-y) \epsilon_{S,ROW} - x \frac{p}{p+c+\tau} \tilde{\epsilon}_{D,EU} - (1-x) \epsilon_{D,ROW}} \quad (2)$$

Note the ratio multiplying the EU demand elasticity. This ratio corrects for the fact that demand depends on the price including the supply costs and taxes and hence that a change in the global oil price  $p$  will have a smaller percentage effect on consumer prices (see Methods for further discussion of this).

The effect of a tax change  $\Delta\tau$  on the oil price can be approximated linearly as

$$\Delta_\tau p \approx \frac{dp}{d\tau} \Delta\tau \quad (3)$$

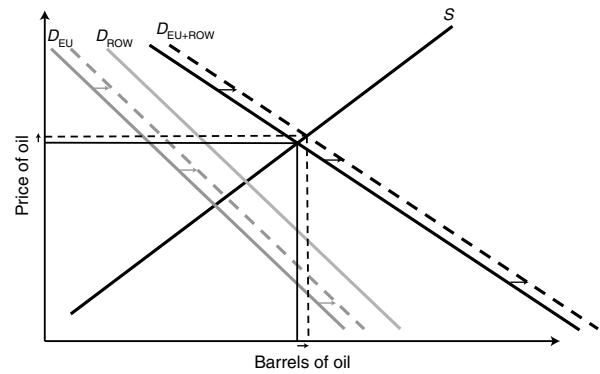
Let the fuel price in the EU be denoted  $f \equiv (1 + \nu_{EU})(p + c + \tau)$ . The change in the fuel price is

$$\Delta_\tau f \approx (1 + \nu_{EU})(\Delta_\tau p + \Delta\tau) \quad (4)$$

The EU's fuel tax revenues are  $T_{EU} \equiv (\nu_{EU}(p + c) + (1 + \nu_{EU})\tau) D_{EU}$  and the fiscal cost of the tax change (that is, the lost tax revenue) can be found by differentiating with respect to  $\tau$ —taking into account that the oil price depends on the tax—and making a linear approximation. The fiscal cost is then

$$\Delta_\tau T_{EU} \approx \left[ 1 + \left( \nu_{EU} + \frac{\tau + \nu_{EU}(p+c+\tau)}{p+c+\tau} \epsilon_{D,EU} \right) \left( 1 + \frac{dp}{d\tau} \right) \right] D_{EU} \Delta\tau \quad (5)$$

Finally, we translate an oil price change into a change in Russian oil profits. The oil profits of Russia are  $\pi_{RU} = (p - e)S_{RU}(p)$ , where  $e$  represents the oil extraction costs, which are assumed to be constant per unit. This assumption is realistic under the production changes considered here. Again, treating  $p$  as a function of  $\tau$ , differentiating



**Fig. 1 | Illustration of supply and demand in the long term.** Oil demand for road transport in Europe ( $D_{EU}$ ) increases by a tax cut (the  $D_{EU}$  demand line shifts to the right from the solid to the dashed line position). Consequently, total world oil demand ( $D_{EU+ROW}$ ) increases by an equal amount (the  $D_{EU+ROW}$  line shifts to the right from the solid to the dashed line position). World oil supply ( $S$ ) is somewhat elastic and a new, higher, equilibrium price is attained at a higher quantity level (dashed lines).

with respect to  $\tau$  and making a linear approximation gives that Russian oil profits change by

$$\Delta_\tau \pi_{RU} \approx \left( 1 + \frac{p-e}{p} \epsilon_{S,RU} \right) S_{RU}(p) \Delta_\tau p \quad (6)$$

As an explicit aim of the tax cut is to shield consumers from increasing fuel costs, an alternative way to do so is to give general income transfers to people that correspond to the reduction in tax revenues that would result from a decreased fuel tax. From a welfare perspective, this is preferable since people can then choose how to use the money. To the extent that the tax cut is supposed to appease particular groups, it is also possible to direct the income transfers to these groups. Such options include giving money to all car owners (not based on their driving), giving money to particular regions where the population is more reliant on cars (for example, rural areas) or reimbursing the tax collected in a region or municipality to that same region or municipality. Another rationale to uphold fuel taxes is to internalize climate damages from fossil fuel use (that is, Pigouvian taxes). From the perspective of this Analysis, an additional effect of an income transfer is that a share smaller than one will be spent on fuel; hence, the increase in Russian oil profits will be smaller. How much smaller will be assessed quantitatively.

To analyse this alternative policy option, we assume that road fuel demand in the EU now depends on disposable income  $I$  in addition to the fuel price. Differentiating the market equilibrium condition with respect to  $I$  and treating the equilibrium price as a function of income, we get that the oil price change due to an income change is

$$\frac{dp}{dI} = \frac{p}{I} \frac{x \epsilon_{I,EU}}{y \epsilon_{S,RU} + (1-y) \epsilon_{S,ROW} - x \frac{p}{p+c+\tau} \tilde{\epsilon}_{D,EU} - (1-x) \epsilon_{D,ROW}} \quad (7)$$

where  $\epsilon_{I,EU}$  is the income elasticity of road fuel demand in the EU. The effects of a change in the disposable income  $\Delta I$  on the oil price,  $p$ , and the fuel price in the EU,  $f$ , are

$$\Delta_I p \approx \frac{dp}{dI} \Delta I \text{ and } \Delta_I f \approx (1 + \nu_{EU}) \Delta_I p \quad (8)$$

The effect on Russian oil profits due to the income transfer is

$$\Delta_I \pi_{RU} \approx \left( 1 + \frac{p-e}{p} \epsilon_{S,RU} \right) S_{RU} \Delta_I p \quad (9)$$

## Data and estimates vary over different time horizons

We quantitatively assess the effects described theoretically in three different cases: the very short term, the short term and the long term. Here, we sketch the qualitative effects in the different time horizons. The size of the effects depends on the numerical values, which are presented at the end of this section. We start by describing the long-term effects. Note that we use long term to describe the effects beyond 1 year, to be thought of as in 1–3 years but not more. Other studies deriving price elasticity estimates often use long term to describe effects on longer time horizons. In the Methods, we discuss our selection and range of elasticity estimates in more detail and how they relate to the time horizon.

In the long term, supply is somewhat elastic and demand is rather elastic too. This is because producers have time to adjust their production and make some capacity investments. Likewise, consumers can acquire new habits or find solutions based on a new fuel price, and those in the process of buying a new vehicle will take the fuel price into account (see, for example, ref. <sup>12</sup>). This is the case illustrated in Fig. 1. The grey lines show the demand from the EU and the rest of the world, respectively. The black lines represent global demand and supply. A tax reduction in the EU shifts the EU's demand outwards (dashed grey line). This in turn increases global demand by an equivalent amount (dashed black line). There are two effects of this: an increase in the oil price (a shift along the vertical axis) and an increase in the quantity of oil produced (a shift along the horizontal axis).

In the short term, to be thought of as 1–12 months, the supply elasticity in terms of quantity is lower than in the long term. This can be seen in Fig. 2a, where supply is illustrated as fixed. Demand elasticity is lower than in the long term since most of the consumer choice regards how much to drive rather than what vehicle to buy or how to change long-term habits. Since, as in the figure, supply is fixed, a reduced tax results in increased oil price but no increase in production or consumption. In practice, some of the increased demand from the EU is attenuated by decreased consumption in the rest of the world.

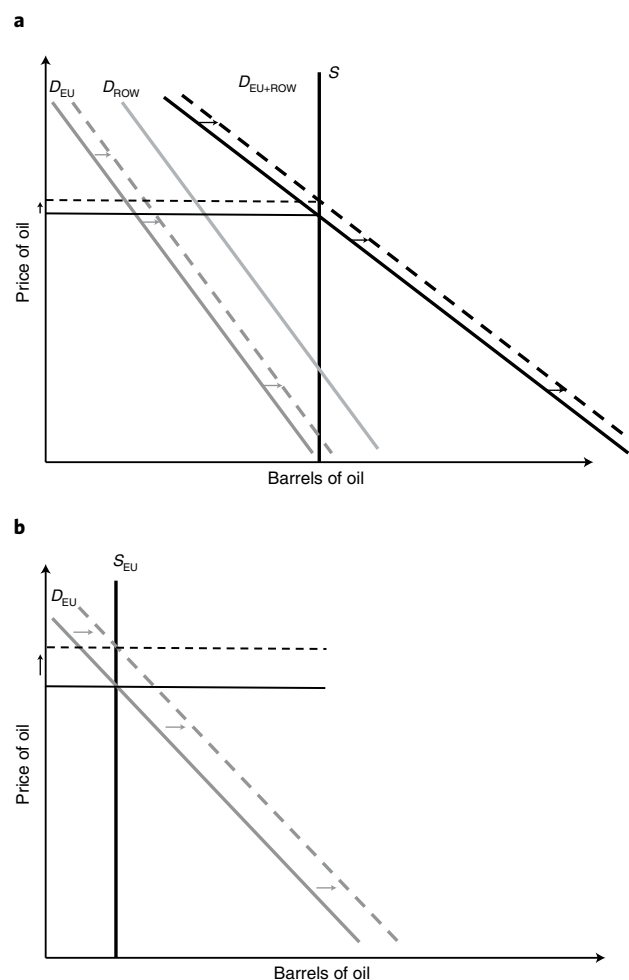
In the very short term, to be thought of as up to 1 month, there are limitations on how much oil, which was originally meant for other markets, can be redirected quickly to the EU. The reason for this is that bilateral contracts of supply can be viewed as partly fixed; oil tankers on their way to one country cannot in the very short term easily be sent elsewhere. To capture this, we model this as though the EU is an isolated oil market. The supply is fixed, both in terms of quantity and who supplies the oil. Implicitly, this also means that the oil price in the EU may differ from the oil price elsewhere. This case is illustrated in Fig. 2b. Importantly, here Russia is relatively a much larger supplier than on the global market. Demand is also less elastic than in the short term. We view our modelling here as a thought experiment. Reality in the very short term probably lies somewhere in between our modelling here and the short-term scenario described above. One simplification and limitation of our model is that we do not consider oil inventories. We discuss the potential effects of an EU import embargo in the next section.

The parameters, quantities and shares in equations (1)–(9) are based on previous research and current data. They are reported in Table 1. Where relevant, we distinguish between very-short-term, short-term and long-term elasticities and shares. Motivations for the values are provided in the table, with further information available in Methods.

In a sensitivity analysis in Supplementary Note 2, we perturb the key parameters to show how this affects our results.

## Effects of fuel-tax cuts on Russian oil income

Here, we analyse the effects of a fuel-tax cut in the very short term, the short term and the long term. The tax cut considered is equivalent to €0.20 l<sup>-1</sup> including VAT (that is, it amounts to €0.2/(1 + VAT)). This is based on a weighted average of currently announced tax cuts in EU



**Fig. 2 | Illustration of supply and demand in the short term and in the very short term. a**, In the short term, oil demand for road transport in the EU ( $D_{EU}$ ) increases by a tax cut (the  $D_{EU}$  demand curve shifts to the right from the solid to the dashed line position). Consequently, total world oil demand ( $D_{EU+ROW}$ ) increases by an equal amount (the  $D_{EU+ROW}$  demand curve shifts to the right from the solid to the dashed position). World oil supply ( $S$ ) is fixed (inelastic) and a new, higher, equilibrium price is attained (dashed line) at the same quantity level. **b**, In the very short term, oil demand for road transport in Europe ( $D_{EU}$ ) increases by a tax cut as in the short term, but due to transport rigidities, the EU is modelled as an isolated market. Hence, the total demand equals EU demand ( $D_{EU}$ ). Supply to the EU ( $S_{EU}$ ) is fixed (inelastic) and a new, higher, equilibrium price is attained (dashed line) at the same quantity level.

countries (equivalent to roughly 10% of the price) and on the possibility that all countries cut the taxes to the EU's minimum level (see the Methods section 'Fuel price and taxes' for details).

The results in the very short term are presented in the top row of Table 2. Of the 20 cents of tax reduction, 7 cents are passed through to oil suppliers. Russia, being an important supplier, attains a large share of the fiscal cost of the policy, making an additional €36 million per day. Apart from financing Russia, the policy is also quite ineffective in lowering consumer prices in the very short term; consumers only experience 12 cents of reduction per litre despite the tax reduction being 20 cents. The results here take into account Russia's current reduced supply to the EU (see the Methods section 'Size of markets and Russian export declines').

In the short-term case, to be thought of as the remaining part of the first year, the consumer price in the EU is reduced by almost the full tax reduction and the now global oil price is increased by much less than in the very short term. Nevertheless Russia—a large supplier

**Table 1 | Parameters for equations (1)–(9) describing Russia's oil income**

Parameter	Variable	Very short term	Short term	Long term	Reference
Demand elasticity of road fuel in the EU with respect to price	$\tilde{\epsilon}_{D,EU}$	-0.25	-0.25	-0.9	See Methods
Demand elasticity of oil globally (excluding EU road fuel) with respect to price	$\epsilon_{D,ROW}$	-0.125	-0.125	-0.45	See Methods
Supply elasticity of Russian oil with respect to price	$\epsilon_{S,RU}$	0	0	0.13	See Methods
Supply elasticity of global oil (excluding Russia) with respect to price	$\epsilon_{S,ROW}$	0	0	0.13	See Methods
Demand elasticity of road fuel in EU with respect to income	$\epsilon_{I,EU}$	1	1	1	Ref. <sup>15</sup>
Base fuel excise tax in the EU (€l <sup>-1</sup> )	$\tau$	0.55	0.55	0.55	Weighted average of all countries' taxes; see Methods
Base oil price per litre of fuel (€l <sup>-1</sup> )	$p$	0.58	0.58	0.58	Oil price=\$110 per barrel; foreign exchange rate=€0.9 per \$; 170l fuel per barrel
Other costs, such as refining (€l <sup>-1</sup> )	$c$	0.45	0.45	0.45	Follows from $p + \tau + c$ ; see Methods
VAT rate	$v_{EU}$	0.2	0.2	0.2	
Base consumer price excluding VAT (€l <sup>-1</sup> )	$p + \tau + c$	1.58	1.58	1.58	Sum of oil price, fuel tax and other costs; see Methods
Oil extraction cost in Russia (€ per barrel)	$e$	17	17l	17	Rystad UCube database <sup>14</sup>
EU road fuel demand share of global oil consumption (%)	$x$	48	5.7	5.7	Refs. <sup>31,32</sup>
Russian oil exports per day (million litres of fuel; million barrels of oil)	$S_{RU}$	540; 3.2	1,200; 7	1,400; 8	IEA <sup>38</sup> and case assumptions; see Methods
Global oil supply, excluding Russian exports, per day (million litres of fuel; million barrels of oil)	$S_{ROW}$	13,000; 7.6	16,000; 92	16,000; 92	Follows from $S_{RU}, S$
Road fuel demand in the EU per day (million litres of fuel; million barrels of oil)	$D_{EU}$	870; 5.1	960; 5.6	970; 5.7	Follows from $x, D$
Global oil demand, excluding EU road fuel demand, per day (million litres of fuel; million barrels of oil)	$D_{ROW}$	950; 5.6	16,000; 93.4	16,000; 94.3	Follows from $x, D$
Russia's exports as a share of the global supply (%)	$y$	29	7	8	Follows from $S_{RU}, S$

**Table 2 | Effect of an EU fuel-tax cut of €0.20l<sup>-1</sup>**

	Oil price change (cents per litre)	EU fuel price change (cents per litre)	Fiscal cost to the EU (million Euros per day)	Profit gain for Russia (million Euros per day)	Profit gain for Russia (million Euros per year)
Very short term	6.7	-12	150	36	-
Short term	0.7	-19	170	8.4	3,100
Long term	0.55	-19	115	8.2	3,000

also globally—is still receiving sizable additional profits (€8.4 million per day or €3.1 billion in year equivalents).

In the long-term case, to be thought of as beyond 1 year and up to 3 years, supply becomes somewhat elastic and so does demand. The price effects are again smaller and the fiscal cost to the EU is smaller than in the very short and short term. This is because, instead of an oil price increase, there is an increase in the supply. Russia's additional oil profits are still sizeable at €8.2 million per day or €3.0 billion per year.

In Supplementary Note 2, we carry out a sensitivity analysis of these results with respect to other parameter values. The results are generally not very sensitive in the very short term. The long-term and

short-term results are more sensitive. The sensitivity analysis suggests that Russia's short-term profit gains can be one-third compared with those using our preferred parameter values (reported here in the main text). However, they may also be around 70% higher. We also investigate whether the discount on Russian oil (through the Urals price) is likely to change our results (Supplementary Note 4) and let the costs  $c$  be proportional to the oil price (Supplementary Note 3). With regard to the Urals price, while the time window is too short to infer the long-term effects, our analysis suggests that an increased global oil price (for example, due to a tax cut, as considered here) will lead to an equivalent increase in the Urals price. Hence, our results are probably not affected by this discount. We refer the reader to Supplementary Note 4 for more details.

A final issue of robustness is whether the results change due to an import embargo. On 3 June 2022, the EU announced an extensive but incomplete import embargo on Russian oil<sup>4</sup> to be imposed with a delay of several months. Had the embargo been imposed before the tax cuts, the particular effects relying on the rigidity of transport would disappear. It would make the mechanisms and results in the very short term identical to those in the short term, which are independent of whether an oil import embargo exists or not. However, since the import embargo will take force with a long delay and since most of the tax cuts have already been implemented, we view the very short-term results presented here as an assessment of what has possibly already

**Table 3 | Effect of a fiscal equivalent cash transfer**

	Oil price change (cents per litre)	EU fuel price change (cents per litre)	Fiscal cost to the EU (million Euros per day)	Profit gain for Russia (million Euros per day)	Profit gain for Russia (million Euros per year)
Very short term	0.91	1.1	150	4.9	–
Short term	0.11	0.13	170	1.3	470
Long term	0.016	0.019	115	0.24	88

materialized. It should be noted that the results for the short and long term are driven by an increase in the global oil price due to higher EU demand. Furthermore, in such time frames, transport routes can be adjusted. Hence, the results in the short and long term are independent of whether or not the EU imposes an import embargo on Russia. As long as there are sufficiently many or large buyers of Russian oil, the market will adjust the trade flows.

Are the additional profits for Russia large? We now discuss this from a few different perspectives. First note that in the very short term, a large share of the EU's fiscal cost (24%) is sent to Russia. In the short term and long term, much less is sent, but still around 5–7% of what is meant to help European consumers is instead going to Russia.

The additional Russian profits are sizeable compared with Russia's pre-invasion GDP, which was about €3.7 billion per day. The EU's tax cut increases Russia's GDP by -1% in the very short term versus 0.2% in the short term and the long term. We can also compare them with Russia's military spending, which was about €160 million per day pre-invasion (based on ref. <sup>13</sup>, the average yearly military spending in 2015–2020 was US\$65 billion; a \$ to € exchange rate of 0.9 makes this €160 million per day). The daily profit increase then corresponds to 23, 5 and 5% of military spending in the very short term, short term and long term, respectively.

Almost all of these revenues stay in the Russian economy as 93% of Russian production is owned by Russian companies<sup>14</sup> (both state owned and privately owned). Rosneft and Gazprom—the two main majority state-owned companies—produce -46% of Russia's oil. The average government take for oil (that is, combined state taxes, tariffs and so on) in Russia is 50% of total revenues<sup>14</sup>. Hence, almost all oil revenues stay in the Russian economy while 50% goes directly to the Russian state as taxes and fees and an additional 23% goes to state-controlled companies.

Finally, it should be noted that the effects are linear in the size of the tax cut. This implies that, should the tax cut be twice as large, the Russian additional profits will be twice as large too, and vice versa in case the tax cut is half of what we study. This follows from our linear approximation (see the section 'Theoretical approach'). This is a reasonable assumption as long as the effects on aggregate global demand and supply are small, which indeed is the case in both the short- and long-term cases. In the very short term (where the EU is a submarket), changes in the tax cut may not scale linearly. This is because, if the tax cut is sufficiently large, the EU demand change is sizeable. Hence, a doubling of the tax cut cannot be assumed to imply doubling of Russian profits; it can be more and it can be less than doubling. One issue that plays a role is whether the elasticities are constant over the demand and supply curves. To date, this is a largely unresolved question in the literature.

### Effects of an alternative direct cash transfer policy

As seen, a fuel-tax cut in the EU provides Russia with a large additional income. Furthermore, part of the help meant for EU fuel consumers in the form of a tax cut is instead passed through to increased oil prices, especially in the very short term. The question is then whether it is possible to help EU consumers in a way that does not benefit Russia. Here,

we look at one such alternative, namely in the form of a cash transfer to consumers with an equivalent fiscal burden to the tax cut. That is, we tie the transfer to €150 million, €170 million and €115 million in the very short, short and long term, respectively.

The results are presented in Table 3. The increased income leads to an increased demand for fuel. However, since the cash can be spent on anything, most of it is used for other things. Hence, the fuel price increases only marginally (1.1 cents in the very short term and much less in the long term). One perspective on this, which highlights the main benefit of cash transfers compared with fuel-tax cuts, is that consumers, through these policies, receive the equivalent of 20 cents per litre of fuel consumed on average. To receive the benefits of a tax cut, consumers have to buy fuel. If they receive it in the form of cash instead, they can choose to spend it all on fuel, to spend none of it on fuel or somewhere in between; cash is a more flexible currency than a tax cut. Even a person who spends the whole transfer on fuel will gain from a cash transfer since the fuel price increases only by 1.1 cents. Therefore, this allows for varying preferences in the population (it is also possible to direct the cash to particular groups that are hit harder by the price increase; see 'Theoretical approach'). Another benefit of a cash transfer is that it avoids decreasing the fuel tax (that is, a Pigouvian tax), thus abating climate concerns.

Perhaps most importantly for the subject matter here, Russia's profit gains are substantially lower with the cash transfer (in the short term -15% of the profits received from a tax cut and in the long term much less). It can be noted that Russia's profits under a cash transfer are also substantially lower when compared with the lowest profits of a tax cut considered in the sensitivity analysis (see Supplementary Note 2).

The conclusion that an income transfer yields much lower Russian profits is not likely to change even if we consider other expenditures of households in the EU. The reason for this is that an income elasticity of 1, as we use here<sup>15</sup>, implies that fuel's share of income is constant when income increases. Put differently, since private road-transport fuels correspond to 7% of consumer spending in the EU (figure for 2008 from ref. <sup>16</sup>), only 7% of the cash transfer would go to road fuel. Transport accounts for 13.2% of households' expenditures<sup>17</sup>, not all of which goes to oil products. Elasticity for other transport is not very different from that for road fuels (for aviation income, elasticity is around 1 (ref. <sup>18</sup>)). Hence, the amount of cash transfer that may go to oil products is effectively capped by oil's cost share in the EU. Elasticities for other categories of consumer spending vary. For food, elasticity is around 0.5 in the EU<sup>19</sup> and it accounts for 14.8% of expenditures, while housing-related expenditures correspond to 25.7% (a small share of which is gas for heating). Various smaller categories correspond to the remaining 48% (ref. <sup>20</sup>).

### Conclusion

We have analysed how much a fuel-tax cut in the EU will increase Russian income from oil. The effects are substantial. A tax cut of €0.20 increases Russia's daily oil profits by €8.4 million during the first year and €8.2 million if it remains longer (in the very short term, the daily profit increase can be substantially higher).

We show that a fiscally equivalent cash transfer can achieve similar alleviation to consumers to a tax cut but with a fraction of the increased profits for Russia.

### Methods

#### Derivation of model

Here, we provide derivations of the model used in the analysis. We distinguish between the demand for crude oil for vehicle fuel in the EU,  $D_{EU}$ , and the remaining oil demand  $D_{ROW}$ . Note that the rest of the world demand includes oil demand in the EU for uses other than vehicle fuel. Since we want to study the effects of taxes on vehicle fuel in the EU, we explicitly consider these and assume that the demand for oil for fuel in the EU depends on the price, including refinement, transportation and

taxes. Let  $p$  denote the crude oil price,  $\nu$  the VAT rate and  $\tau$  the per-unit tax on vehicle fuel in the EU. The costs for refinement and transportation could have one per-unit component,  $c$ , and one component proportional to the price,  $z$ . We thus have the fuel price

$$f = (1 + \nu)((1 + z)p + c + \tau) \tag{10}$$

and crude demand in the EU depends on this price and on income  $I$ ,  $D_{EU}(f, I)$ . The rest of the world demand depends directly on the crude oil price  $D_{ROW}(p)$ . In the baseline model, we focus on per-unit costs, corresponding to  $z = 0$ . In the Supplementary Information, we instead consider completely proportional costs, corresponding to  $c = 0$ .

The supply is a function of the crude oil price and we distinguish between oil supply from Russia,  $S_{RU}(p)$ , and supply from the rest of the world,  $S_{ROW}(p)$ .

The world market price of crude oil is determined by the equilibrium in the global oil market:

$$D_{EU}(f, I) + D_{ROW}(p) = S_{RU}(p) + S_{ROW}(p). \tag{11}$$

### Model of fuel-tax cut

Treating the equilibrium price  $p$  as a function of  $\tau$ , and differentiating both sides fully with respect to  $\tau$ , taking equation (10) into account, gives

$$(1 + \nu) \frac{\partial D_{EU}(f, I)}{\partial f} \left( (1 + z) \frac{dp}{d\tau} + 1 \right) + D'_{ROW}(p) \frac{dp}{d\tau} = \left( S'_{RU}(p) + S'_{ROW}(p) \right) \frac{dp}{d\tau} \tag{12}$$

Let  $D$  and  $S$  denote total demand and supply and let  $x$  and  $y$  denote shares of demand and supply as given by

$$D_{EU} = xD, D_{ROW} = (1 - x)D, S_{RU} = yS \text{ and } S_{ROW} = (1 - y)S. \tag{13}$$

Multiplying the left- and right-hand sides of equation (12) by  $p/D$  and  $p/S$ , respectively (with  $S = D$  in equilibrium), yields

$$\frac{dp}{d\tau} = \frac{(1 + \nu) \frac{p}{D} \frac{\partial D_{EU}(f, I)}{\partial f}}{\frac{p}{S} S'_{RU}(p) + \frac{p}{S} S'_{ROW}(p) - (1 + \nu)(1 + z) \frac{p}{D} \frac{\partial D_{EU}(f, I)}{\partial f} - \frac{p}{D} D'_{ROW}(p)}.$$

Using equation (13) and multiplying the terms containing the derivative of  $D_{EU}$  by  $f/f$ , we get

$$\frac{dp}{d\tau} = \frac{\frac{(1 + \nu)p}{f} \frac{x f}{D_{EU}} \frac{\partial D_{EU}(f, I)}{\partial f}}{\frac{y p}{S_{RU}} S'_{RU}(p) + \frac{(1 - y)p}{S_{ROW}} S'_{ROW}(p) - \frac{(1 + \nu)(1 + z)p}{f} \frac{x f}{D_{EU}} \frac{\partial D_{EU}(f, I)}{\partial f} - \frac{(1 - x)p}{D_{ROW}} D'_{ROW}(p)}.$$

Using equation (10), we arrive at

$$\frac{dp}{d\tau} = \frac{x \frac{p}{(1 + z)p + c + \tau} \tilde{\epsilon}_{D,EU}}{y \epsilon_{S,RU} + (1 - y) \epsilon_{S,ROW} - x \frac{(1 + z)p}{(1 + z)p + c + \tau} \tilde{\epsilon}_{D,EU} - (1 - x) \epsilon_{D,ROW}}, \tag{14}$$

where we have the price elasticities of supply

$$\epsilon_{S,RU} \equiv \frac{p}{S_{RU}} S'_{RU}(p) \text{ and } \epsilon_{S,ROW} \equiv \frac{p}{S_{ROW}} S'_{ROW}(p) \tag{15}$$

and demand

$$\tilde{\epsilon}_{D,EU} \equiv \frac{f}{D_{EU}} \frac{\partial D_{EU}(f, I)}{\partial f} \text{ and } \epsilon_{D,ROW} \equiv \frac{p}{D_{ROW}} D'_{ROW}(p). \tag{16}$$

We can differentiate the fuel price from equation (10) with respect to  $\tau$  to get

$$\frac{df}{d\tau} = (1 + \nu) \left( (1 + z) \frac{dp}{d\tau} + 1 \right).$$

The changes in the oil price  $p$  and the EU fuel price  $f$  induced by a change  $\Delta\tau$  in the tax can be linearly approximated as

$$\Delta_\tau p \approx \frac{dp}{d\tau} \Delta\tau \text{ and } \Delta_\tau f \approx (1 + \nu) \left( (1 + z) \Delta_\tau p + \Delta\tau \right). \tag{17}$$

The EU tax revenues associated with fuel contain both the direct VAT revenue and the excise duty with VAT applied to it:

$$T_{EU} = (\nu((1 + z)p + c) + (1 + \nu)\tau) D_{EU}(f, I).$$

Differentiating this fully with respect to  $\tau$  gives

$$\begin{aligned} \frac{dT_{EU}}{d\tau} &= [\tau + \nu((1 + z)p + c + \tau)] \frac{\partial D_{EU}(f, I)}{\partial f} \left[ (1 + \nu) \left( (1 + z) \frac{dp}{d\tau} + 1 \right) \right] \\ &\quad + \left[ \nu \left( (1 + z) \frac{dp}{d\tau} + 1 \right) + 1 \right] D_{EU} \\ &= (1 + \nu) \frac{\tau + \nu((1 + z)p + c + \tau)}{f} \frac{f}{D_{EU}} \frac{\partial D_{EU}(f, I)}{\partial f} \left[ (1 + \nu) \left( (1 + z) \frac{dp}{d\tau} + 1 \right) \right] D_{EU} \\ &\quad + \left[ \nu \left( (1 + z) \frac{dp}{d\tau} + 1 \right) + 1 \right] D_{EU} \\ &= \left[ 1 + \left( \frac{\tau + \nu((1 + z)p + c + \tau)}{(1 + z)p + c + \tau} \tilde{\epsilon}_{D,EU} + \nu \right) \left( (1 + z) \frac{dp}{d\tau} + 1 \right) \right] D_{EU}. \end{aligned}$$

Multiplying by  $\Delta\tau$  and using  $\Delta_\tau f$  from equation (17) delivers a linear approximation of the change in tax revenues from the tax change  $\Delta\tau$ :

$$\Delta_\tau T_{EU} \approx \left[ \Delta\tau + \left( \frac{\tau + \nu((1 + z)p + c + \tau)}{(1 + z)p + c + \tau} \tilde{\epsilon}_{D,EU} + \nu \right) \left( (1 + z) \Delta_\tau p + \Delta\tau \right) \right] D_{EU}.$$

The Russian oil profits are

$$\pi_{RU} = (p - e) S_{RU}(p),$$

where  $e$  represents Russian extraction costs that are assumed to be constant.

Treating  $p$  as a function of  $\tau$  and differentiating fully with respect to  $\tau$  gives

$$\frac{d\pi_{RU}}{d\tau} = \frac{dp}{d\tau} S_{RU} + (p - e) S'_{RU}(p) \frac{dp}{d\tau} = \left( 1 + \frac{p - e}{p} \epsilon_{S,RU} \right) S_{RU} \frac{dp}{d\tau}$$

and, using  $\Delta_\tau p$  from equation (17), a linear approximation of the change in Russian oil profits is

$$\Delta_\tau \pi_{RU} \approx \left( 1 + \frac{p - e}{p} \epsilon_{S,RU} \right) S_{RU} \Delta_\tau p.$$

### Model of income transfer

Here, we consider the effects of transferring income to households instead of lowering the fuel tax. Treating the equilibrium oil price as a function of  $I$ , differentiating equation (11) fully with respect to  $I$  and using equation (10) gives

$$\frac{\partial D_{EU}(f, I)}{\partial I} + \frac{\partial D_{EU}(f, I)}{\partial f} (1 + \nu)(1 + z) \frac{dp}{dI} + D'_{ROW}(p) \frac{dp}{dI} = \left( S'_{RU}(p) + S'_{ROW}(p) \right) \frac{dp}{dI}. \tag{18}$$

Multiplying the left- and right-hand sides of equation (18) by  $p/D$  and  $p/S$ , respectively (with  $S = D$  in equilibrium), we get

$$\frac{dp}{dI} = \frac{\frac{p}{D} \frac{\partial D_{EU}(f, I)}{\partial I}}{\frac{p}{S} S'_{RU}(p) + \frac{p}{S} S'_{ROW}(p) - (1 + \nu)(1 + z) \frac{p}{D} \frac{\partial D_{EU}(f, I)}{\partial f} - \frac{p}{D} D'_{ROW}(p)}.$$

Using equation (13) yields

$$\frac{dp}{dI} = \frac{\frac{p}{I} \frac{\partial D_{EU}(f,I)}{\partial I}}{\frac{y}{S_{RU}} S'_{RU}(p) + \frac{(1-y)p}{S_{ROW}} S'_{ROW}(p) - \frac{(1+\nu)(1+z)p}{f} \frac{\partial D_{EU}(f,I)}{\partial f} - \frac{(1-x)p}{D_{ROW}} D'_{ROW}(p)}$$

Using equations (10), (15) and (16), we arrive at

$$\frac{dp}{dI} = \frac{p}{I} \frac{x\varepsilon_{I,EU}}{y\varepsilon_{S,RU} + (1-y)\varepsilon_{S,ROW} - x\frac{(1+z)p}{(1+z)p+c+\tau}\tilde{\varepsilon}_{D,EU} - (1-x)\varepsilon_{D,ROW}}$$

where the income elasticity of demand in the EU is

$$\varepsilon_{I,EU} \equiv \frac{I}{D_{EU}} \frac{\partial D_{EU}(f,I)}{\partial I}$$

The responses of the oil price  $p$  and the EU fuel price  $f$  to an income change  $\Delta I$  can be linearly approximated as

$$\Delta_I p \approx \frac{dp}{dI} \Delta I \text{ and } \Delta_I f \approx (1 + \nu)(1 + z) \Delta_I p. \tag{19}$$

Treating  $p$  as a function of  $I$ , differentiating oil profits  $\pi_{RU} = (p - e) S_{RU}(p)$  fully with respect to  $I$  and using the Russian supply elasticity in equation (15) gives

$$\frac{d\pi_{RU}}{dI} = \frac{dp}{dI} S_{RU} + (p - e) S'_{RU}(p) \frac{dp}{dI} = \left(1 + \frac{p - e}{p} \varepsilon_{S,RU}\right) S_{RU} \frac{dp}{dI}$$

and, using equation (19), a linear approximation of the change in Russian oil profits is

$$\Delta_I \pi_{RU} \approx \left(1 + \frac{p - e}{p} \varepsilon_{S,RU}\right) S_{RU} \Delta_I p.$$

### Parameter values of elasticity of demand

The price elasticity of demand for road transport fuels (gasoline and diesel) and crude oil is low in the short term but increases with time. In the short term, many fuel consumers can only drive less to reduce consumption, while in the longer term many can shift to more efficient vehicles or change their commuting distance or mode of transportation.

Several studies compile existing estimates of the demand elasticity of gasoline, diesel and crude oil (see, for example, refs. 21–24). These estimates are derived using different methods over different time periods and locations. Short-term gasoline elasticity estimates range from  $-0.04$  to  $-0.5$  (refs. 23,24) with several review studies deriving averages around  $-0.25$  (ref. 24). Aklilu<sup>24</sup> also provides additional original estimates for EU countries using recent data, finding an EU average short-term gasoline elasticity of  $-0.255$ . We use  $-0.25$  in our calculations, in line with these recent EU estimates as well as the wider literature samples.

Long-term gasoline demand elasticity estimates range from  $-0.2$  to  $-1$  (ref. 23). Aklilu<sup>24</sup> compiles review studies with even higher ranges but with averages around  $-0.7$ . Aklilu's own empirical study finds a long-term EU average of  $-0.88$ . We use  $-0.9$  in our calculations based on these results.

Crude oil demand elasticity is usually found to be lower than that of gasoline. This is to be expected since crude oil is only a part of the gasoline price. If we assume that crude oil represents half the cost of retail gasoline, a 10% increase in the price of crude oil would translate to a 5% increase in the price of gasoline, and the demand elasticities for oil would be about half those for gasoline<sup>21</sup>. Caldara et al.<sup>22</sup> compile 31 studies for short-term world oil demand in the range of  $-0.04$  to  $-0.9$  with a mean of  $-0.22$  and a median of  $-0.13$ . We follow Hamilton<sup>21</sup> and use half of the gasoline estimates for wider oil demand (that is,  $-0.125$  for our short-term oil demand elasticity and  $-0.45$  for our long-term

oil demand elasticity), which is also in line with the estimates of Caldara et al.<sup>22</sup>

In the sensitivity analysis in Supplementary Note 2, we also explore lower and higher values in the range found in the literature.

### Parameter values of elasticity of supply

The price elasticity of global oil supply is low (close to zero) in the short term and grows only slowly in the longer term. New conventional oil fields take several years to bring into production and additional supply in the short term (within 1 year) can only come from either inventory, politically withheld supply (including, for example, Saudi Arabian spare capacity), shale oil production and infill drilling in conventional fields.

Compared with demand elasticity studies, supply elasticity studies are rare. Caldara et al.<sup>22</sup> compile six studies applying different methods and data and find short-term (within 1 year) supply elasticities in the range of  $0$ – $0.27$ . These estimates are based on historical data and do not necessarily reflect current or future oil supply. As a complement, we also rely on modelled forward-looking estimates of supply elasticity derived by Wachtmeister<sup>25</sup> using a bottom-up modelling framework and Rystad UCube field-by-field data, as well as our own judgement of the current oil market outlook.

For our very-short-term and short-term scenarios, we use a supply elasticity of  $0$  for both Russia and the rest of the world. This corresponds to a hypothetical scenario with no inventory draw, no additional production by the Organization of the Petroleum Exporting Countries and a timeframe below 6 months where the shale response is still low. In the sensitivity analysis (Supplementary Note 2), we present a short-term case using  $0.1$ , which can be seen as reflecting a 12-month shale response and/or a stronger response from the Organization of the Petroleum Exporting Countries.

For our long-term scenario, we use  $0.13$ , which is in line with a modelled 3-year horizon estimate of global supply by Wachtmeister<sup>25</sup>. A value of  $0.13$  is also used as a central estimate by Erickson and Lazarus<sup>10</sup>, even though their studied time horizon is longer than ours. In the sensitivity analysis (see Supplementary Note 2), we explore  $0.2$  as a higher estimate, reflecting a stronger supply response.

Note again that our long-term scenario reflects a supply response in 1–3 years. Other studies reporting long-term supply elasticity estimates might use long term to describe longer time horizons. For example, Gately<sup>26</sup>, Brook et al.<sup>27</sup> and Erickson and Lazarus<sup>10</sup> use long term to describe responses up to 15 years ahead.

### Other costs and refinery margins

We translate oil production (crude oil, condensate and natural gas liquids) in barrels per day to a corresponding volume of refined products. We make the simplifying assumption that one barrel of oil yields 170 l of products and fuels that can be sold to consumers. In the base case, the variable production cost of these fuels is assumed to correspond directly to the crude oil price (that is, the variable fuel production cost is the global oil price per barrel (Brent; in US\$ per barrel) measured in Euros per litre of fuel product ( $p$ )). The retail fuel price (consumer price) is then the variable fuel production cost (oil price,  $p$ ) plus the other, fixed, production costs,  $c$  (refining, transport, margins and so on), plus the fuel tax,  $\tau$ , then VAT is applied to all of these. In the sensitivity analysis (see Supplementary Note 3), we explore other variable production costs ( $z$ ) and discuss which case is more likely. Our base case  $c$  of  $\text{€}0.45 \text{ l}^{-1}$  is derived backwards from a consumer price of  $\text{€}1.9 \text{ l}^{-1}$ .  $c$  thus includes the current refinery margins (the value difference between crude oil and refined products), which vary in time and are currently at historically high levels.

### Size of markets and Russian export declines

We assume that Russia has already lost 1 million barrels per day of oil exports based on recent export data<sup>28</sup> and analysis<sup>29</sup>. In January, before the war, the global supply and demand of oil was estimated to be 100 million barrels per day (ref. 30). Consequently, we assume

the current oil market to be 99 million barrels per day. Road transport fuel's share of total EU oil consumption is 47.5% (ref. <sup>31</sup>). The EU's share of global oil consumption is 12% (ref. <sup>32</sup>), which yields our  $x = 0.475 \times 0.12 = 5.7\%$ . The EU imports, in normal times, -35% of its oil from Russia<sup>33</sup>. For the very short term, we assume that the reduction in Russia's export (1 million barrels per day) fully accrues to the EU. This implies  $y = 29\%$  in the very short term.

### Fuel price and taxes

For our analysis, we need to construct an EU-level fuel price and fuel tax. However, fuel prices and taxes differ between the EU countries. We construct EU-level values using weighted averages based on each country's share of total EU fuel consumption using data from Eurostat<sup>34</sup>. The data underlying the quantification in this section are summarized in Supplementary Table 1.

For the country-level fuel price, we use data from the European Commission (from the fuel-prices.eu database<sup>35</sup>). We use the average prices for the month of May 2022 (see columns 3 and 4 of Supplementary Table 1) and obtain weighted averages of €1.89 l<sup>-1</sup> for petrol and €1.87 for diesel. Hence, we choose €1.9 as transport fuel price.

In assessing the EU's tax reduction, we want to emphasize that announced and implemented tax reductions come in several forms (for example, excise duty reduction and directed VAT reductions), new ones are being suggested and their time spans are varied. Hence, there is scarcely any way to assess the final aggregate outcome until possibly several years from the time of writing. Instead, to obtain a rough estimate of what the final outcome may be, we look at two scenarios.

The first scenario is based on the possibility that all EU countries reduce their excise tax to the EU minimum level (€0.359 l<sup>-1</sup> for unleaded petrol and €0.33 l<sup>-1</sup> for diesel). In this scenario, we use the countries' tax levels from July 2021 (ref. <sup>36</sup>) and reduce them to the minimum level (we use the numbers for unleaded petrol and gas oil for propellant use (diesel); in some instances, different tax levels apply to different sub-categories, in which case we take an average). The data are summarized in columns 5–8 of Supplementary Table 1. We then obtain a weighted average tax reduction of €0.24 for petrol and €0.15 for diesel (these do not include the indirect effects on VAT that apply to excise duties).

The second scenario (columns 9 and 10 in Supplementary Table 1) takes the post-invasion announcements to date (mid-June 2022). For this, we take the compilation of Transport & Environment<sup>37</sup>, cross-check their entries with news articles and add directed VAT reductions for fuels (for Estonia and Romania). For most countries, we verify the numbers from Transport & Environment<sup>37</sup> (see the footnote of Supplementary Table 1). We interpret (but ultimately cannot verify) the numbers to exclude the indirect effects on VAT payments in those cases (such as Germany) where VAT applies to the excise duty (the number for Sweden in Supplementary Table 1 includes this indirect VAT effect). The most consequential decision is probably our choice to set Poland's pre-invasion VAT reduction to zero. In calculating VAT reductions in Euros, we use the average price in January and February 2022 (this is conservative since prices were lower than post-invasion). We then obtain a weighted average tax reduction of €0.165 l<sup>-1</sup> for petrol and €0.132 l<sup>-1</sup> for diesel. We also calculate the percentage reduction in fuel taxes. We obtain percentage reductions for petrol and diesel of 9.7 and 8.2%, respectively, compared with the price in January and February, 8.8 and 7.4%, respectively, compared with the 3-month pre-reduction average price and 5 and 4.3%, respectively, compared with the price in May. These numbers are not shown in Supplementary Table 1.

Based on these scenarios, each with its own caveats, we use a tax reduction of €0.20 (including indirect VAT effects) for the analysis.

### Data availability

All of the data generated or analysed during this study are included in this published article (and its Supplementary Information files) or are publicly available.

### Code availability

Model implementation code written in MATLAB is available as Supplementary Code.

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## Author contributions

All of the authors contributed equally to the project. J.G., D.S. and H.W. together designed the study, developed the methodology, interpreted the results and wrote and edited the manuscript. H.W. led the data and input parameter work, J.G. led the model implementation. D.S. led the coordination of the project.

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## Competing interests

The authors declare no competing interests.

## Additional information

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