

POLICY BRIEF

Optimal tariff versus optimal sanction: The case of European gas imports from Russia

Abstract

Europe has set itself the aim of reducing its dependency on Russian gas imports. This note provides an economic analysis of a tariff on imports of natural gas into the EU which would help achieve this goal. The starting point is that Gazprom has a monopoly on exports of gas from Russia. Standard trade theory implies that even on purely economic grounds a tariff on Russian gas imports would be beneficial for Europe because it would lower the demand curve Gazprom faces and induce it to lower prices.

The standard linear model used here takes into account the availability of LNG (Liquid Natural Gas) supplies confirms the general rule that it pays to levy a tariff on imports from a foreign monopolist and yields these numerical results:

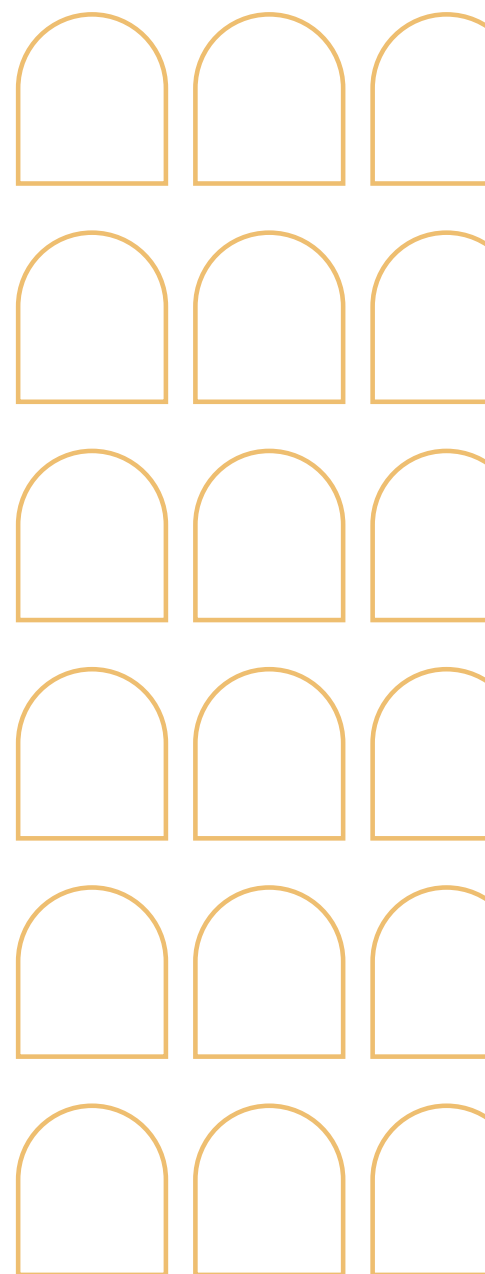
- Only one half of the tariff would result in higher prices for European consumers and the tariff revenue would be more than sufficient to compensate them for this loss.
- The tariff which maximises Europe's welfare would be close to one third of the price at which Europe would stop importing from Russia. This would cut Gazprom's net revenues approximately to one half.
- If the tariff is used as a sanctions weapon to reduce revenues for Russia, the tariff should be higher (around 60%) and would cut Gazprom's revenues to one fourth of the free trade level.
- Even at this higher level of tariff the home country would be better off than under free trade.

The overall conclusion is thus that an EU import tariff on Russian gas would have a major impact on Russia's gas export earnings, would certainly improve the European terms of trade and would strengthen Europe's independence from Russian gas.

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Introduction

The ongoing suffering of the civilian population in Ukraine has led to calls for the EU, or individual Member States, to ban imports of Russian gas.¹ The economic consequences of such a step would be very severe in the short run.² But there is another way, more gradual, which would minimize economic disruptions and which would have a strong impact on the revenues flowing to Russia. The EU should simply impose a special import tariff on Russian gas.

Such a move would of course be against WTO rules. But under these special circumstances it can be justified with the exemption under article XXI for national security. Moreover, Russia has imposed for a long time an export tax of 30% on gas. The EU can claim that its import tariff just compensates for this distortion.³

A tariff could be implemented almost overnight; and given that it would be done at the EU level it would provide a tangible sign that Member countries can act together.

The political advantage of a tax on imports of gas from Russia are also clear.

First of all, it would counter, at least partly, the argument that by importing gas from Russia we are financing Russia's war of aggression. Those who still buy Russian gas would then also contribute to finance our reaction to this war and the tariff would provide them with a strong price signal to diversify over time. Those who have alternatives will do so immediately. The demand for Russian gas in Europe will fall, slowly at first, but at an accelerating rate.

Secondly, it would yield substantial revenues. At present high global natural gas prices, a 30% tariff on the value of Russian gas could easily reach 30-50 billion euro (on an annual basis) at the level of the EU. This would allow the EU to provide assistance for vulnerable groups being hit by higher gas prices, further assistance to the Ukrainian government and help Member States to defray the costs of caring for the millions of refugees we must expect. If, as now unfortunately seems likely, 3-5 million Ukrainian have to seek shelter in the EU, the overall costs could

also be in the order of dozens of billions euro (counting over 10 thousand euro per refugee for housing and living expenses).⁴

A further advantage of this approach would be that it would provide a very strong long-term incentive for the private sector to seek other supplies. And these supplies would be forthcoming. If the EU makes it clear that the tariff is going to stay as long as Russia's aggression against Ukraine continues, other potential suppliers of gas around the world will take notice and start investing in finding new sources or exploit better existing ones. Gros (2022b) argues that in Asia there is considerable potential for energy savings and switching from gas to coal, thus liberating important quantities of LNG supplies for Europe.

There is little Russia can do to avoid this tax on its exports to the EU because it cannot simply sell its gas somewhere else. With 140 bcm, the EU accounts for about 70% of overall Russian pipeline gas exports. The other customers are unlikely to be able to compensate fully for the EU market. China takes already substantial amounts of gas from Russia and will not want to become dependent on Russia for its energy. As the biggest buyer, the EU has considerable 'monopsony power', which should be used to counteract the monopoly position of Gazprom.⁵

The purpose of this contribution is to apply a standard partial equilibrium trade model to the specific situation of the European gas dependency from a monopolistic supplier, i.e. Gazprom. The case at hand is thus different from the usual models which assume that foreign supply is provided by competitive firms (see for example Sturm (2022)). Taking into account the monopoly position of Gazprom implies that even on strictly economic grounds a tariff on Russian gas would increase EU welfare.

Moreover, Gazprom cannot be considered as a private sector supplier. It represents the interests of the Russian government, and its revenues finance the Russian war effort. This implies that the standard two country models must be modified.

One could of course object, that Russia could react to the European import tariff by increasing

1 This section is based on Gros (2022)

2 For an estimate see Baqaee et al (2022).

3 See Tarr (2004) for an economic analysis of Russia's dual pricing in the WTO context.

4 See OECD (2017) for estimates of the per capita cost of refugees in OECD countries between 10 and 20 thousand dollar.

5 For the classic reference on monopsony power see Johnson (1968). Russia has some LNG export facilities, but they are close to fully used and can thus not constitute a safety valve.

its own export tariff. This might very well be the case. But Russia's export tariff is of little importance. It determines only the domestic price level for gas (see Tarr (2004) on the reasons why Russia wants to keep dual pricing). The lower that level the more gas will be wasted inside Russia. The domestic price level for gas inside Russia is anyway fixed in roubles and has thus already gone down relative to the world market price level. The Russian export tariff has thus de facto already increased.

The following section set out the essential elements of a standard model, the cost structure of the foreign monopolist, the demand curve for Russian gas in Europe, the pricing power and thus profits of the foreign monopolist. This is then followed by the determination of the tariff which yields the highest welfare for Europe (optimal tariff) and the tariff which would in addition reduce the revenues of Gazprom at an acceptable price for Europe (optimal sanction).

A standard model

Here we present a standard partial equilibrium model of a country which imports a good from a foreign monopolist. This foreign monopolist cannot sell the same good in third countries, at least not at the price charged to European customers.⁶ This gives the home country monopsony power, which is not used under free trade.

In the following it is assumed that the marginal cost of supplying this good is constant, given by:

$$\text{Equation 1} \quad \text{Marginal cost} = c$$

One could argue that in the short run the cost of pumping gas to Europe is zero as the pipelines are readily available and the fields have been developed with the aim to export to Europe. Moreover, Gazprom does not have immediately enough other customers for the gas coming out of existing fields. But it has always the option of pumping less, thus keeping it for future sales. The assumption of a zero marginal cost thus does not seem appropriate; but it also not central to the results presented here as all the results would still hold if marginal costs were zero.

The following presents the simplest case of linear demand and supply curves. The annex

briefly analyses the more general case of any downwards sloping demand curve. Annex II also provides in Figure A1 the standard diagrammatic exposition of the case for a tariff when the home country faces a foreign monopolist. The figure cannot show what the magnitude of the optimal tariff would be and how it would affect the revenues of the foreign monopolist. This is why it is necessary to derive the analytical solutions, starting from the core element, namely the demand function for gas.

Deriving the European demand for Russian gas

The starting point is that the overall quantity of gas demanded in Europe is a declining function of the price:

$$\text{Equation 2} \quad \text{Demand in EU} = D - d_e p$$

Where p represents the price paid by European consumers. There is one integrated European market in this model. The price is the same for all countries, independently of whether they import their gas from Russia or sources (piped from Norway or Algeria, LNG from the Middle East). The impact of changing gas prices or a tariff thus does not depend on the amount of gas imported from Russia, but only on the overall imports of gas.

A key feature of the global market for natural gas is that Europe is the marginal or balancing market where both piped gas and LNG are available. This means that that LNG can constitute an alternative source of supply for Europe.

Asia (rather the big Asian importers of gas like China, Japan and South Korea) depend almost entirely on LNG supplies, which arrive there via tankers from major exporters like Australia and the Middle East (Qatar, for example). This representation of the supply from Asia implicitly considers only the net balance between the producers and consumers, where additional net supply can result in the short run only by energy savings by Asian consumers (Gros (2022a).

It is assumed here that LNG supplies are subject to increasing marginal cost because transport is more costly and because substitution of gas

⁶ Jones and Takemori (1989) discuss in detail what constellation of market segmentation would be required.

by oil or coal in power generation in Asia can liberate supplies for Europe, but at increasing costs.

Equation 3
$$\text{Supply from Asia} = -S_a + s_a p$$

Where the term $-S_a$ indicates that at very low prices in Europe gas would flow from Europe to Asia. The parameter S_a thus indicates the overall strength of Asian demand whereas the parameter s_a indicates the strength of the reaction of Asian demand to higher prices (thus liberating supplies for Europe). Given that more gas is being used for power generation in Asia than in Europe one could argue that $s_a > d_e$, but this is not essential and will not be assumed in the following.

The availability of LNG supplies means that European demand for Russian gas is given by:

Equation 4

$$\text{Demand for Russian gas} =$$

$$\text{Overall demand in EU} - \text{supply from Asia}$$

$$= D + S_a - d_e p - s_a p$$

The slope of the European demand curve for gas from Russia is thus determined by the sum of the reactivity of demand for gas inside the EU plus the potential supply from Asia. For the subsequent analysis it will be more convenient to express the (European) demand curve for Russian gas in terms of the price European customers are willing to pay. Inverting equation 4 and denoting the quantity imported by Europe by q this can be written as:

Equation 5

Where r is defined as $r \equiv 1 / (d_e + s_a)$, and $R \equiv (D + S_a) / (d_e + s_a)$, $p = (D + S_a) / (d_e + s_a) - q / (d_e + s_a) = R - r q$ is defined as $R \equiv (D + S_a) / (d_e + s_a)$.

The composite parameter R has a decisive influence on the results presented below. R will be higher the higher are the intercepts (D and S_a) and it will be lower the stronger are both price effects on quantities demand (s_a and d_e).

Monopolistic pricing

If Russian gas were supplied competitively to Europe the European price would be fixed at the Russian marginal cost (so long as Europe imports gas from Russia). Indicating this price with p_{com} one can write:

Equation 6

$$p_{com} = c$$

However, Russian gas is supplied only by one firm, Gazprom. One must thus assume that Gazprom acts as a monopolist.⁷ It will then set the marginal revenue equal to marginal cost.

Total revenue is given by

Equation 7

$$p = R q - r q^2$$

It follows that setting marginal revenue equal to marginal cost plus a potential tariff, denoted by t , yields:

Equation 8

$$MR = (R - 2rp) = c + t$$

For ease of computation we concentrate on the case of a specific tariff of rate t (meaning t euro per cubic meter). Russia imposes an export tariff on gas (until recently of 30%). However, the size of the Russian export tariff is irrelevant here since the aim of Gazprom is simply to maximise its revenues from gas exports. The domestic Russian price, which is much lower, is only a residual quantity.

The quantity which Gazprom will offer (denoted by q_t), is thus linearly related to the tariff:

Equation 9

$$q_t = \frac{R - c - t}{2r}$$

The price which Gazprom will charge European consumers can be obtained by substituting this relationship back into the demand curve, which yields:

⁷ It is possible that Gazprom does not only acts with commercial interests as it is state owned, but this issue is not pursued here.

Equation 10

$$p_t = R - r \frac{R-c-t}{2r} = \frac{1}{2}(R + c + t)$$

$$= c + \frac{1}{2}(R - c + t) > c$$

Equation 9 implies, as one would expect that Gazprom will charge a positive price even if its marginal cost were zero. The price it charges will depend on the parameter R , which incorporates the availability of supplies from Asia. The higher the reactivity of Asian to supply to higher prices (the higher s_a), the lower will be the price Gazprom charges in Europe.

The price which the monopolist charges is higher than the competitive price as long as $R > c$, i.e. the marginal value of a small amount of Russian imports is higher than the marginal cost for Gazprom (plus the tariff). In the following it will be assumed that this is the case.

The formula for the price level replicates the well-known result that with a linear demand curve, the monopolist lowers the net of tariff price by one half of the tariff so that the price for consumers increases only by one half of the tariff. The tariff revenue would be more than enough to compensate consumers since the net price for the economy falls, i.e. the terms of trade improve. The net of tariff price is given by:

Equation 11

$$p_t - t = \frac{1}{2}(R + c - t)$$

It can now be shown that the total profits of Gazprom are a declining function of the tariff.

Profits of the foreign monopolist

In the present situation the revenues accruing to Russia because of continuing European gas imports have become a focus of attention.

The net profits of Gazprom are given by the difference between its total revenues, minus the costs and the tariff paid:

Equation 12

$$Net\ profits\ Gazprom = Rq - rq^2 - tq - cq$$

Where the subscript t for the quantity demanded (indicating that it depends on the tariff rate) has been suppressed for notational convenience. The expression for net profits can be written more compactly as a function of the parameters of the demand curve by using the relationship between the quantity demanded and the tariff.

Equation 13

$$Net\ profits\ Gazprom = q(R - t - c) - rq \left[\frac{R-c-t}{2r} \right]$$

Which can be simplified to:

Equation 14

$$Net\ profits\ Gazprom = q \left(R - t - c - \frac{R-c-t}{2} \right) = \frac{(R-c-t)^2}{2}$$

Net profits for Gazprom decline as the tariff increases; they are also an increasing function of R . In both cases the relationship is quadratic, i.e. convex. The marginal impact of increasing the tariff is higher when starting from a high level of the tariff, than when starting at zero. The same applies to the intercept parameters (the strength of European and Asian demand for gas).

If one parameterizes the tariff in terms of a fraction of $(R-c)$, e.g. by $t = \alpha(R-c)$ (it will be shown below that this is an optimal policy, of course with $\alpha < 1$) one can rewrite the expression for Gazprom's net profits as:

Equation 15

$$Net\ profits\ Gazprom = \frac{((R-c)(1-\alpha))^2}{2r}$$

As Gazprom acts as a monopolist, free trade is not appropriate for Europe. But this raises the question how high should the tariff be. Here we consider two cases:

1. The 'normal' case of the optimum tariff literature. The home country (Europe) should increase the tariff up to the point where the loss of consumer surplus from the tariff equals the gain through better terms of trade. This case is standard in the literature.
2. 'Optimum sanction'. Here the objective function is different given the present case

of a conflict where the revenues accruing to Gazprom have a negative utility for Europe because they help to finance a war of aggression. This provides an additional argument for a tariff.

Standard optimum tariff

In the standard optimum tariff case the home country cares only about its own welfare. The size of the optimum tariff can be calculated by maximising European welfare, which is given by the integral under the demand curve, minus the net of tariff revenues paid to Gazprom.

Equation 16 *Home country welfare* = W_{OT} :

$$= \int_0^{qt} (R - rq) dq - (p - t)q = \frac{1}{2} (R - c + t)q - \frac{r}{2} q^2$$

The optimum tariff rate maximises this welfare, subject to the reaction function of the foreign monopolist. The marginal impact of a tariff on home welfare is given by:

Equation 17 $\frac{\partial W_{OT}}{\partial t} = \frac{1}{2} \left\{ (R - c + t) \frac{dq}{dt} + q - 2rq \frac{dq}{dt} \right\}$

Which can be simplified to:

Equation 18 $\frac{\partial W_{OT}}{\partial t} = \frac{1}{4r} \{ (R - c) - 3t \}$

The optimum tariff is attained when , which implies (see annex for details):

Equation 19 $t_{OT} = \frac{(R-c)}{3}$

The ‘normal’ optimum tariff is thus equal to one third of the difference between the price that would obtain if imports from Russia were banned and the marginal cost. Given that present spot prices might well reflect the fear of a complete import ban (and given that the marginal cost is an order of magnitude lower) this would mean that the optimum tariff could be about one third of today’s spot price.

Equation 18 implies that the optimum tariff is an increasing function of the parameter R (defined in equation 5, above). The value of R is decreasing in the sum of the slope coefficients of the European and Asian demand schedules. The more reactive demand is, the lower will be the optimum tariff. The intercepts of European and Asian demand, which denote their strength have the opposite effect. Strong demand in either or both regions justifies a higher tariff.

The annex shows that with a more general demand function one obtains the standard result that the tariff should be equal to the absolute value of the elasticity of demand. Estimates of the elasticity of demand for gas vary and are usually higher in the longer run. Auffhammer and Rubin (2018) report estimates between 0.2 to 0.3, which would be similar to the result found here.

Imposing the optimum tariff would have a strong impact on Gazprom’s net profits. Using equation 15 above, with $\alpha = 1/3$, implies that Gazprom’s profits would fall by the factor $4/9 = (2/3)^2$:

Equation 20

$$\frac{\text{Net profits Gazprom optimum tariff}}{\text{Net profits Gazprom no tariff}} = (1 - \alpha)^2 = \left(\frac{2}{3}\right)^2 = \frac{4}{9}$$

Just imposing the optimum tariff would thus already deprive Gazprom of more than half of its profits.

Optimum sanction

The optimum tariff argument assumes that the home country is indifferent about the size of the (remaining) profits of the foreign producer. However, this is not the case at present because the profits of Gazprom support a war of aggression in Ukraine. The purpose of a sanction is always to impose a cost on the adversary, not (as the optimum tariff) to increase home welfare.

To capture the idea that the purpose of a sanction is to reduce the income of the adversary it is assumed here that the net profits of Gazprom enter the utility function of Europe negatively.⁸

In this case foreign profits lower home country welfare, which is now given by.

8 More precisely, each euro of net profits for Gazprom is equivalent to one euro lost for Europe. The implicit reasoning could be that the resources flowing to Gazprom support the war effort, requiring an equivalent effort on the European side.

Equation 21

$$\begin{aligned} \text{Home country welfare} &= W_{OS} = \\ &= \int_0^{q_t} (R - rq) dq - q(p - t) - q(p - t - c) \\ &= Rq - \frac{r}{2} q^2 - 2q(p - t) + cq \end{aligned}$$

The result of the maximisation of the expression with respect to the choice of t following the same procedure as above (setting the derivative with respect to t equal to zero) yields (see annex for details):

Equation 22

$$0 = \frac{1}{4r} [3(R - c) - 5t]$$

This implies that the optimum ‘sanctioning’ tariff is given by:

Equation 23

$$t_{OS} = \frac{3}{5} (R - c)$$

Which is considerably higher than the standard optimum tariff, but not quite as punitive as the 90% proposed by Hausmann (2022). A tariff equivalent to 60% of the cut-off price would anyway reduce the net profits of Gazprom drastically. Using again equation 15 with $\alpha=2/5$ it follows that Gazprom’s profits would fall to about one sixths of the free-trade (status quo) level:

Equation 24

$$\frac{\text{Net profits Gazprom optimum sanction}}{\text{Net profits Gazprom no tariff}} = (1 - \alpha)^2 = \left(\frac{2}{5}\right)^2 = \frac{4}{25}$$

Welfare comparison

It is difficult to compare welfare under the two different hypothesis considered above. Normally one compares free trade (FT) to the optimum tariff (OT). However, one cannot compare these two to the optimum sanction (OS) case because the latter contains a different argument (namely the desire to reduce revenues for the foreign country).

It follows that if the home country (Europe) does not care about the net revenues of Gazprom, the

optimum tariff is better than free trade.

However, if the revenues of Gazprom affect Europe’s welfare negatively, welfare is higher with the optimum sanction tariff than either free trade or the tariff set at the optimum tariff.

If only domestic variables count one thus has, a usual:

Equation 25

$$W_{OT} > W_{FT}$$

In a sanctions environment one has

$$W_{OS} > W_{\text{tariff at OT level}} > W_{\text{no tariff}}$$

Equation 26

The simple conclusion is that the tariff rate should be increased beyond the standard optimum tariff level if reducing the flow of resources becomes an additional aim of policy.

In an environment in which only the welfare of the home country enters into the utility function one can still compare the welfare levels between the free trade level and the tariff set at the optimal sanctions level. As in equation 16 above one has:

Equation 27

$$W_{\square} = \int_0^{q_t} (R - rq) dq - (p - t)q = \frac{1}{2} (R - c + t)q - \frac{r}{2} q^2$$

This can be rewritten as:

Equation 28

$$\begin{aligned} W_{\square} &= \frac{1}{2} (R - c + t)q - \frac{r}{2} q^2 = \\ &= \frac{1}{2} (R - c - t) \left[R - c - t - \frac{1}{2} (R - c - t) \right] \\ &= \frac{1}{8} (R - c - t) [R - c + 3t] \end{aligned}$$

It is now straightforward to compute the welfare level for three cases: $t=0$ (free trade), $t= (R-c)/3$ (optimal tariff) and $t= 2(R-c)/3$ (optimal sanction)

The results are as follows:

Equation 29

$$W_{FT} = \frac{1}{8}(R - c)[R - c] = \frac{1}{8}(R - c)^2$$

Equation 30

$$W_{OT} = \frac{1}{8} \cdot \frac{2}{3}(R - c)2[R - c] = \frac{1}{8} \cdot \frac{4}{3}(R - c)^2$$

Equation 31

$$W_{OS} = \frac{1}{8} \cdot \frac{2}{5}(R - c) \cdot \frac{14}{5}[R - c] = \frac{1}{8} \cdot \frac{28}{25}(R - c)^2$$

The last result is key. Comparing equation 31 to 29 shows that the welfare level of the home country is still higher than free trade level even if the tariff is set much higher than the optimal tariff. The gain from better terms of trade are so strong that they outweigh the high distortion created by a tariff set at the optimum sanctions level. Setting the tariff at this level represents thus the ultimate smart sanction: it reduces the welfare of the foreign country and improves even (slightly) home welfare.

Conclusion

The starting point of the simple model used here is that Gazprom has a monopoly position on the European gas market. Its monopoly power is constrained in the medium run by the potential for energy savings and Europe and potential gas supplies from Asia. However, it is strong in the short run.

In the present situation European side private sector entities compete for Russian gas. The import tax would put a price on two external effects which our importers ignore so far. The first is the (pecuniary) externality is that each individual importer drives up the price, thus increasing our terms of trade loss. The second externality is that each individual importer increases our collective dependency on Russian gas and provides more revenues for the Russian war effort.

The model confirms two standard results:

1. Free trade is not the optimum in this case.
2. The foreign monopolists will increase its price only by a fraction (one half) of the tariff and the government would have more than enough revenues to compensate all consumers for the higher price.

The linear demand function used here to calculate orders of magnitude for further aspects:

1. The tariff which maximises Europe's welfare would be close to one third of the price at which Europe would stop importing from Russia (or to be more precise one third of the difference between that price and the marginal cost of Russian gas).
2. A tariff of this size (about 30%) would cut Gazprom's net revenues approximately to one half. But this would be just a side effect, not the main aim of the tariff.
3. If the tariff is used as a sanctions weapon to reduce revenues of Gazprom, the tariff should be higher and would cut Gazprom's revenues to one fourth of the free trade level.
4. Even at this higher level of tariff the home country would be better off than under free trade.

The overall conclusion is thus that an EU import tariff on Russian gas would have a major impact on Russia's earning from gas exports and would certainly improve the European terms of trade.

The main political objection against a tariff is that it further increase gas prices. However, any quantitative restriction on Russian gas imports into the EU would have the same effect (unless gas is rationed). A complete embargo on gas imports would drive prices even higher. A tariff remains the most efficient means to reach the goal of reducing Russia's revenues from gas.

Finally one has to ask how Europe would achieve the aim of reducing gas imports from Russia without resorting to a tariff. The only alternative would be quantitative restrictions or outright orders to energy distribution companies not to buy Russian gas. The latter would be difficult to sustain from a legal point of view and the former would be equivalent to a tariff if the rights to imports Russian gas are auctioned. If they are just distributed on political grounds this would result a massive distribution of rents. The European Commission has recently presented ideas how the EU could achieve independence from Russian energy 'well before 2030'. But the Commission document (European Commission (2022)) describes only what sources could substitute Russian gas, but not how or why private sector gas users should reduce their purchases of Russian gas.

At any rate, one has to keep in mind that any given reduction in Russian gas imports whether achieved through quantitative restrictions, licensing or a tariff leads to the same increase in gas prices. The main difference a tariff makes is that the link between the reduction of gas imports and higher prices becomes more transparent.

Annex

Derivation of analytical expression for the optimal tariff and optimal sanction:

Optimal tariff

$$\begin{aligned}\frac{\partial W_{OT}}{\partial t} &= \frac{1}{2} \left\{ (R - c + t) \frac{dq}{dt} + q - 2rq \frac{dq}{dt} \right\} \\ &= \frac{1}{2} \left\{ (R - c + t) \frac{dq}{dt} + 2q \right\} \\ &= \frac{1}{2} \left\{ (R - c + t) \frac{-1}{2r} + 2 \frac{R - c - t}{2r} \right\} \\ &= \frac{1}{4r} \{ (R - c) - 3t \}\end{aligned}$$

Where the expression for the price is used $1/2 (R + c - t) q = p$ in the total revenue pq . The other individual steps should be self-explanatory.

$$\begin{aligned}\frac{\partial W_{OT}}{\partial t} &= \frac{1}{2} \left\{ (R - c + t) \frac{dq}{dt} + q - 2rq \frac{dq}{dt} \right\} \\ &= \frac{1}{2} \left\{ (R - c + t) \frac{dq}{dt} + 2q \right\} = \frac{1}{2} \left\{ (R - c + t) \frac{-1}{2r} + 2 \frac{R - c - t}{2r} \right\} \\ &= \frac{1}{4r} \{ (R - c) - 3t \}\end{aligned}$$

The second order condition for a maximum is satisfied as the second derivative is negative.

Optimum sanction:

$$\begin{aligned}\text{Home country welfare} &= W_{OS} = \\ &= \int_0^{q_t} (R - rq) dq - q(p - t) - q(p - t - c) \\ &= \int_0^{q_t} (R - rq) dq - \frac{2}{2} (R + c - t) q + cq \\ &= q[R - R - c + t - c] - \frac{r}{2} q^2 = qt - \frac{r}{2} q^2 \\ \frac{\partial W}{\partial t} &= t \frac{dq}{dt} - rq \frac{dq}{dt} + q = \frac{-t}{2r} + q \left[1 + \frac{r}{2r} \right] \frac{dq}{dt} = \\ &= \frac{1}{2r} \left[\frac{3}{2} (R - c - t) - t \right] \\ &= \frac{1}{4r} [3(R - c) - 5t]\end{aligned}$$

Part II General demand curve

Here we consider the more general case of a demand given by $p=f(q)$.

Total revenue is then given by $TR=qf(q)$.

The condition that marginal revenue equals marginal cost for the foreign monopolist can then be written as:

$$c + t = f(q) + qf'(q)$$

This implies that the quantity sold by the monopolist is related to (changes in) the tariff by:

$$dq(f'(q) + f'(q) + qf''(q)) = dt$$

Which implies that:

$$\frac{dq}{dt} = \frac{1}{(2f'(q) + qf''(q))}$$

This can also be used to calculate the impact of the tariff on prices, which is given by:

$$\frac{dp}{dt} = \frac{f'}{(2f'(q) + qf''(q))} = \frac{1}{2} + \frac{f'}{qf''(q)}$$

The price paid by consumers increases thus by one half if f'' is small (the linear case considered in the text).

Social welfare is given by the integral under the demand curve minus the net of tariff revenues accruing to the monopolist (q_t indicates the quantity imported into Europe with a tariff at rate t).

$$W_{\square} = \int_0^{q_t} (f(q)) dq - (p - t)q_t$$

The total differential of W can be calculated as:

$$dW = f(q) \frac{dq}{dt} - (f(q) - t) \frac{dq}{dt} - dqf'(q) \frac{dq}{dt} + q$$

Cancelling the first two terms on the RHS, multiplying by (dq/dt) and setting dW equal to zero yields:

$$\begin{aligned}t &= qf'(q) - q \frac{dt}{dq} = q(f'(q) - 2f'(q) + f''(q)) \\ &= q(f''(q) - f'(q))\end{aligned}$$

This expression shows the solution for the optimal tariff under more general conditions. But it is also more difficult to interpret in terms of observables. For the linear case ($f'' = 0$) it can also be rewritten as:

$$t = -f'(q) \Rightarrow \frac{t}{f(q)} = -\frac{f'(q)}{f(q)} q$$

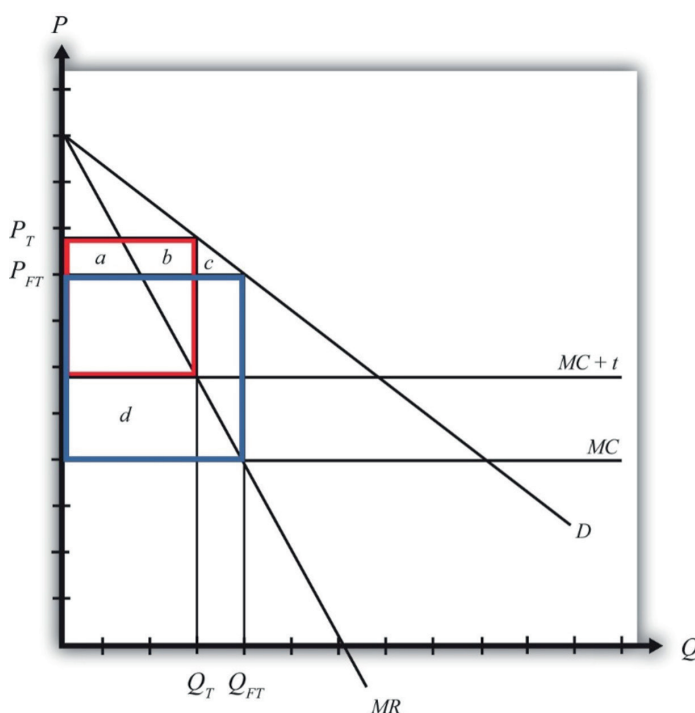
The standard result obtains here as well: the optimal tariff is equal to the negative of the (inverse) of the elasticity of demand for the product in question.

Annex II

Diagrammatic textbook exposition:

The figure below illustrates the linear case used in the text. MC denotes the marginal cost, D demand and MR is marginal revenue. QFT denotes the quantity imported under free trade, and QT the quantity imported with a tariff (or rate t).

Figure A1



Source: https://saylordotorg.github.io/text_international-trade-theory-and-policy/s12-06-the-case-of-a-foreign-monopoly.html#:~:text=Thus%20a%20tariff%20can%20raise%20monopolist%20to%20the%20domestic%20government.

Effect on Importing Country	
Consumer Surplus	$-(a + b + c)$
Producer Surplus	0
Govt. Revenue	$+ d$
National Welfare	$d - (a + b + c)$

The importing country gains if $d > a+b+c$, which will always be the case for a small tariff.

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