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Dual Sourcing and Resilient Supply Chains: The Case of Essential Resources

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Abstract The resilience of supply chains is analyzed in a model of strategic technology investments in markets with essential resources. With a monopoly supplier, dual sourcing is a strategy to reduce switching costs in the long-run. It serves as an insurance mechanism against future opportunism by providing access to competitive global markets. Investments in dual sourcing are required to limit abuse of market power by the active source provider, even though the option of dual sourcing may not be exercised in equilibrium. The analysis has implications for the European natural gas market. Liquefied natural gas terminals may serve a strategic purpose of limiting ex-post opportunism even when delivering gas by pipeline is more efficient.

Keywords Dual sourcing · Resilience · Switching costs · Predatory investments · Supply security · Geopolitics

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Introduction

Motivation

The developments in the energy sector during recent years highlight the risks involved in extensive outsourcing as realized geopolitical risks have contributed substantially

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to interrupt supply chains. Dependency of energy suppliers has been turned into a political weapon as the events linked to the Russian war on Ukraine showcases. From a wider perspective, dependency on essential inputs (e.g., chips or rare materials) has moved to front and center in international politics reducing substantially the expected benefits from free trade.

Also prior to the Russian war, the costs of dependency on foreign suppliers were highlighted by trade interruptions due to border closings right at the start of the coronavirus 2019 (COVID-19) pandemic. Even before the start of the Russian war, an intensive political debate focused on whether globalization had gone too far and how globalization should be redesigned in order to benefit from international trade and concurrently deal with supply chain disruptions (Grossman et al., 2021).

In this article the role of dual-sourcing, or more generally multi-sourcing, is analyzed as a strategy to hedge supply chain risks in a geopolitical context. It is shown that multi-sourcing can be viewed as an investment in increasing the resilience of supply chains by reducing dependency on political risks in the future. The short-term investment costs may well be justified by the long-term gains in resiliency. Multi-sourcing is particularly valuable in an environment with limitations on private contracting.

Argument in a Nutshell

The experience of the gas market between Germany and Russia around the Nord Stream pipelines serves as a motivating example illustrating our argument. While the institutional setting will closely follow a particular case, this paper abstracts from many of its idiosyncratic details. For example, the paper will not discuss the full set of political objectives and (potential) considerations of the supplier country (Russia) or of the buying country (Germany). Rather, the analysis will focus on the arguably subordinated objectives of revenue maximization.[1]

Consider two firms S (supplier) and P (producer), operating at different levels of the supply chain with each operating as monopolists located in different countries with a world market as an essential resource. Firm S is state-owned and located in a country rich in resources. It can deliver the input required for crucial production at a price well below the world market price. Delivering the input exclusively to firm P's production technology requires an infrastructure investment, for example, a pipeline. Access to the world market also requires an infrastructure investment into, for example, a liquefied natural gas (LNG) terminal. Processing natural gas is cheaper than liquid gas. Accordingly, if both infrastructures were available and gas sold at the same price at any desired quantity, in equilibrium, liquid gas would never be used by firm P.

However, firm S has market power and can affect the price of gas delivered through the pipeline. For purposes of illustration, assume that firm S has full monopoly power such that the price of gas delivered through the pipeline is determined exclusively by S. Whereas S has every incentive to promise low prices before and during the investment stage, once the pipeline is finished, economic incentives

[1] The purpose of the analysis is not to offer a complete ex-post explanation of what happened, but rather to show how the excessively costly disruptions could have been avoided by proper ex-ante investments.

lead *S* to charge profit-maximizing prices. These profit-maximizing prices depend on prior investments of firm *P*. If firm *P* made adequate investments into LNG terminals, the market power of supplier *S* would be limited by the advantage in the marginal costs of natural over liquid gas in production. Supplier *S* will face incentives to price gas at just the right level that producer *P* never finds it optimal to actually use liquid gas in any meaningful quantity. In this case, it appears that investment in the construction of LNG-terminals inflicted unnecessary costs. However, this impression is seriously misleading because, in the absence of such investments, producer *P* is vulnerable to much higher monopolistic squeezes for the essential resource. If producer *P* has not invested in access to the world market (i.e., into the LNG-terminal), supplier *S* could easily appropriate private profits plus welfare in producer *P*'s country via a non-linear pricing scheme, extracting all the producer profits and associated consumer welfare from country *P*.

This example illustrates that dual sourcing can be an effective strategy to secure delivery of the resource at the world market price. Dual sourcing can mitigate politically motivated geopolitical price risk,[2] even when the option of dual sourcing is not actively exercised, i.e., no units of input acquired through shipments to the LNG terminal. The cost of establishing the capacity for dual sourcing appears like an insurance premium which eliminates strategic supply chain risk. The strategy of economizing on the construction of LNG terminals in order to secure delivery at prices well below the world market exposes the producer and its country to high risks. Sticking to a hypothetical promise of prices persistently below the world market price is not in the true interest of the supplier, and, hence, not credible (Selten, 1965) nor time consistent (Kydland & Prescott, 1977).

Relevant Literature

There is a wide range of literature on the phenomenon of outsourcing, which has been an instrumental pillar of globalization (Grossman et al., 2021; Grossman & Helpman, 2005). Whereas Grossman et al. (2021) focused on general equilibrium models of trade, the current paper follows Shy and Stenbacka (2003, 2005) and others in analyzing the strategic sourcing decisions of the individual firm in a partial equilibrium setting. This allows for a discussion of outsourcing strategies in greater detail. While the original literature on outsourcing focused on deterministic production processes, the picture changes drastically in markets under conditions of uncertainty and/or strategic risk. In such markets, Grossman et al. (2021) argued in favor of diversification among suppliers. While diversification takes place across firms and industries in their specific setting, in the present framework, strategic risk diversification emerges across infrastructure technologies in otherwise homogeneous

[2] By, geopolitical price is meant an increase in prices in order to raise revenues necessary to finance, for example, war-related activities. This geopolitical price risk should be differentiated from strategic hold-up risk, because it is motivated by political considerations outside the specific market. Clearly, in any specific context, it may be difficult to effectively differentiate between these intention-based concepts.

product markets. This diversification takes place even when potentially dominated technologies are not actively used in equilibrium. The outside option of seemingly dominated delivery channels provides a cap on strategic risk.[3]

In this work, dual sourcing serves as a hedge against ex-post abuse of market power. Accordingly, the current paper is related to two fields of literature: (i) contractual solutions of ex-post opportunism and financial hedging and (ii) organizational design as an instrument of balancing market power.

In a geopolitical setting, contractual solutions and financial hedging are limited by the lack of cross-border legal enforcement institutions. As such, for example, options-based solutions to the hold-up problem (e.g., Nöldeke & Schmidt, 1995) were not available in the current context.

Organizational design as an instrument of balancing market power has been studied by a number of authors. Inderst (2008) demonstrated that single sourcing is not optimal for a buyer facing suppliers with sufficiently convex costs unless the buyer has sufficiently strong market power. Both Du et al. (2006) and Stenbacka and Tombak (2012) presented arguments for dual sourcing as strategies to increase producer bargaining power. More precisely, they presented a model where dual sourcing is an organizational mechanism to balance cost advantages from outsourcing against associated increases in a subcontractor's bargaining power. Likewise, Hubert and Ikonnikova (2011) and Ikonnikova and Zwart (2014) identified dual sourcing as a way of balancing bargaining power by applying cooperative bargaining solutions. One major disadvantage of cooperative solutions, such as the Nash bargaining solution, is that such solutions are silent about the (out-of-equilibrium) event of a breakdown in negotiations, which lies at the heart of the current analysis. Therefore, such models intrinsically cannot address the type of geopolitical risk considered herein.[4] For current purposes, a strategic approach is required that explicitly allows for cooperative agreement breakdowns, be they in equilibrium or out-of-equilibrium.[5] Yang et al. (2012) studied the strategic arguments for dual sourcing when facing suppliers with private information regarding the probability of delivery disruption. All these bargaining games apply cooperative solution concepts that do not allow for out-of-equilibrium play or the probability of bargaining breakdowns. Unlike those approaches, the current study models a strategic game, where dual sourcing provides insurance against idiosyncratic risk as well as the risk of out-of-equilibrium play, or simply strategic mistakes.

[3] There is a related literature focusing on the long-run costs of outsourcing in a research and development (R&D) context. For example, Reitzig and Wagner (2010) argued that outsourcing may seriously affect the knowledge base of innovators in the long-run. Implicitly, their argument also relies on a stochastic context with long-run risk.

[4] While cooperative bargaining solutions can be microfounded by strategic bargaining equilibria in repeated relationships (Rubinstein, 1982), the very realization of geopolitical risk in our framework results in the breakdown of the relationship between producer and supplier.

[5] Clearly, at the stage of Nord Stream negotiations, the German partners did not expect the breakdown in arrangements with Russia, which ultimately happened. This risk of breakdown cannot materialize in a cooperative bargaining solution.

Multi-sourcing can also be seen as a mechanism to balance bargaining power by reducing switching costs across suppliers, i.e. across the supplier and the world market. In this sense, our work relates to Gehrig and Stenbacka (2004, 2007) who analyzed strategic investments in the creation of switching costs, and their reduction as in the present model.

Finally, this work relates to the literature on predatory investments,[6] whenever such investments (in infrastructure) are undertaken by the supplier in order to establish a monopoly position. Such predatory investments have been described in various industries (e.g., IT, Solar, Pharma) as well as in the extraction of natural resources in African countries. In those cases, dual sourcing provides effective insurance against the abuse of market power since it limits expropriation by the monopolist.

Framework of Analysis

Consider a world with two commodities, a final product and an essential resource required for production of the final good. The resource needs to be transported from the supplier to the producer. Geopolitical risk arises whenever the supplier and the producer are located in different countries.

Transportation Infrastructure

There are various modes of transportation of resources from the supplier to the producer. Both require relation-specific investments. One technology connects the producer to the world market like a harbor with terminals that allows ships of different input suppliers to deliver the resource. This technology opens up global competition across suppliers of the input. The technology requires considerable fixed costs $F^w > 0$, for example, the investment to build an LNG terminal, but it secures for the producer access to delivery of the input at the world market price p^w.[7]

The alternative is a supplier-specific technology like a pipeline from the supplier directly to the producer. This technology does not require any liquefaction, transportation by sea, or regasification. Moreover, this technology is also potentially attractive for the producer if it secures access to a low-cost input supplier willing to sell the resource below world market prices. However, by its very nature it connects producer and supplier in a bilateral monopoly configuration. The analysis concentrates on the case when the construction of the pipeline does not impose any costs on the producer P in the final goods market.[8]

[6] For an overview of models of predation, refer to Chapter 7 in Motta (2004).

[7] This price refers to the total costs for the producer. As pointed out by a reviewer, in natural gas markets, the quoted price typically includes delivery to a specific port, but not the cost of regasification nor the cost of transfer to the final destination.

[8] This assumption is consistent with the motivating example that Gazprom funded and has a high ownership share of the Nord Stream 2 pipeline.

In principle, also the supplier could invest in the technology giving access to the world market, which would permit selling the resource at world market prices, or below. In this case, the cost of a pipeline could be saved but at the same time the option to exploit economic dependency at a later stage would be foregone. Moreover, extra costs would have to be incurred for first liquefaction and then degasification for transportation via the world market. For the purpose of this paper, such considerations will be sidestepped since the pipeline was built for whatever reasons and aspirations.[9,10]

Market Structure

The producer enjoys a downstream monopoly and faces a demand function $D(p)$.[11] The risk-neutral producer buys the input either at the world market price p^W and/or from the supplier at p^S and then charges product market price p in order to maximize expected profits. The foreign supplier S can produce the essential resource at a cost c well below the world price $c < p^W$. It is assumed that the supplier maximizes expected revenues. A key question to be analyzed in this paper is why the supplier might be willing to sell the resource below world prices in situations where the monopoly price exceeds this world price.

Whereas the underlying economic arguments are fairly general, for expositional reasons it is convenient to focus on a linear demand function, i.e. $D(p) = a - bp$. Moreover, it simplifies the analysis to assume that the foreign supplier S has all the bargaining power in the bilateral relationship with the producer P and can quote a profit-maximizing price p^S for the input within the supplier-specific delivery channel.[12] In this channel, the supplier has complete discretion over prices and can change them whenever opportune.

Sequence of Decisions

Consider a three-stage game. In the first stage, the producer makes decisions about infrastructure investments, which are long-term strategic decisions. At stage two, the supplier makes decisions about delivery prices p^S. At stage three, the producer sells the final product to the market at a profit-maximizing uniform price p.

[9] Below an argument will be provided to explain why investment in the pipeline might actually be strategically stable when the supplier's discount rate is sufficiently lower than the producer's.

[10] Interestingly, after Russia reduced deliveries through the pipeline and thereby effectively raised ex-post prices on German gas deliveries, it started selling idle supply to its neighboring countries including China as well as to India well below world market prices.

[11] This assumption is made for analytical simplicity. In the motivating example, the German firm E.On took over Ruhrgas in 2004 in a case heavily contested by the German antitrust authority as well as the impartial Monopoly Commission (Hellwig, 2022a).

[12] Again this is a simplifying assumption. In a bilateral monopoly, one could as well follow Ikonnikova and Zwart (2014) and apply a cooperative bargaining solution. However, as in the motivating example, the realization of geopolitical risk would imply that the ex-post bargaining power is shifted to the supplier. This is what essentially happened in the summer of 2022 before the blow-up of the Nord Stream 2 pipeline.

1. Infrastructure choice: The producer decides about adoption of technologies for delivery. The options are: access to the world market at cost F^W, a supplier-specific delivery option with the cost F^S carried by the supplier, or a combination of both delivery technologies.
2. Supplier S quotes input price p^S.
3. Producer P quotes price p for the final good.

A straightforward interpretation of the infrastructure investments in the context of the world gas market could be LNG terminals, that provide access to ships from all over the world. The supplier-specific technology is a pipeline that connects supplier and producer directly, but excludes delivery to others. After the decision regarding infrastructure of delivery has been made, prices are determined. Supplier-specific prices can be modified in the short term in a discretionary way. In contrast, potential changes in infrastructure investments at a later time would require significant extra expenses and implementation time.

Analysis

Producer Pricing and Profit

The final producer takes resource prices r as given and chooses the final product price p in order to maximize revenues:

$$p = argmax_p(a - bp)(p - r) = \frac{1}{2}\left(\frac{a}{b} + r\right),$$

where $\mathrm{r} = p^W$ in case delivery of the marginal unit takes place in the world market or $r = p^S$ with supplier-specific delivery from S. Accordingly, the producer demands a quantity of $q = \frac{a-br}{2}$, from the world market or from the supplier S, respectively.

As long as $r \leq \frac{a}{b}$, the equilibrium profits of the producer are

$$\Pi(\mathrm{r}) = \frac{(a - br)^2}{4b}.$$

This equilibrium profit product is decreasing as a function of the resource cost r.

Supplier Pricing and Profit

Single Sourcing

A supplier as the only provider of the resource within a supplier-specific delivery framework will select a profit-maximizing price according to

$$p^S = argmax_p \frac{a - bp}{2}(p - c) = \frac{1}{2}\left(\frac{a}{b} + c\right),$$

At this price, the supply is $q^S = \frac{1}{4}(a - bc)$ and the supplier earns revenues of

$$\Gamma^S = \Gamma\left(p^S\right) = \frac{(a - bc)^2}{8b}$$

whereas the producer earns only half of the rent in a single sourcing equilibrium:

$$\Pi^S = \Pi\left(p^S\right) = \frac{(a - bc)^2}{16b}.$$

This is the well-known double marginalization result familiar from vertical monopoly chains (Spengler, 1950). In this delivery chain, the supplier can extract a higher share of the rent generated in the output market. This result generalizes to a more general bargaining context between the supplier and producer as long as the bargaining power of the supplier exceeds that of the producer.[13]

Dual Sourcing

Next suppose that the producer has access to the world market and that the world market imposes competitive pressure on supplier specific input delivery. Formally, it is assumed that $p^W < \frac{a+bc}{2b}$ so that the world market prevents the single supplier from exploiting complete monopoly power. Under such circumstances, the supplier will just meet the world price in order to deter the producer from actively purchasing from the world market.

In these circumstances, the supplier's equilibrium revenues are lower than those under single sourcing:

$$\Gamma^W = \frac{a - bp^W}{2b}\left(p^W - c\right) \quad < \quad \Gamma^S = \frac{(a - bc)^2}{8b}.$$

As long as the supplier enjoys cost advantages relative to the world market, i.e., $c < p^W$, the equilibrium revenues of the final goods producer are still lower than those of the supplier. Further, the output market producer's equilibrium revenues associated with dual sourcing exceed those associated with single sourcing[14]:

$$\Pi^W = \frac{\left(a - bp^W\right)^2}{4b} > \Pi^S = \frac{(a - bc)^2}{16b}.$$

[13] Vertical integration is typically the standard solution to the double marginalization problem. However, in a geopolitical context such a solution may not be feasible.

[14] Since the establishment of dual sourcing includes fixed investment costs for infrastructure, while by assumption the input supplier bears the costs of infrastructure under single sourcing, the overall comparison of equilibrium profits remains unclear.

This revenue comparison reveals the advantage of dual sourcing as a mechanism to limit the supplier's market power. This advantage is particularly strong when access to the world market is cheap, but it also occurs, when the supplier enjoys cost advantages in delivery. Finally, the technology choice in the first stage will be analyzed.

Technology Choice

If the supplier enjoys significant cost advantages relative to the world market, she has strong incentives to invest in the distribution technology to supply the producer.[15] However, the question remains whether the producer invests to establish infrastructure that secures access to the world market. Such infrastructure requires costly investments that, in a first-best world, could be saved if the supplier delivers the resource at prices below the world market price in a single-sourcing arrangement. Indeed, at the investment stage, the supplier has all kinds of incentives to promise low price deliveries in the future in order to discourage the producer from investing in dual-sourcing technology. However, such promises are not credible, as time-consistent behavior defines a temptation to raise prices to the profit-maximizing level after investments have been made. As established later in the ex-post taxation discussion, such price increases will be particularly strong in the single-sourcing environment and can only be curbed if dual-sourcing investments have been made.

Overall, the funding of the relationship-specific delivery channel (the pipeline) facilitates a predation strategy by S. In this predation strategy, recoupment of the early infrastructure investments (into the pipeline) is importantly based on the fact that the producer cannot easily switch to the world market after S starts exploiting its market power. Rather, the faster P needs to build the infrastructure for dual sourcing, the more costly it will be. This feature is well illustrated by the costs and difficulties for Germany associated with the establishment of LNG capacity[16] in response to Gazprom's price increases and subsequent closedown of its delivery of natural gas. In order for infrastructure investments to take place in equilibrium, the gains in expected revenues need to dominate the investment costs required for access to the dual source.

Proposition 1 (Dual Sourcing)

The producer will choose dual sourcing in equilibrium if and only if

$$\Pi^W - \Pi^S = \frac{\left(a - bp^W\right)^2}{4b} - \frac{(a - bc)^2}{16b} \geq F^W.$$

[15] In this sense, it is not by chance that Gazprom is the operator and majority stakeholder (51%) of Nord Stream (2023).

[16] According to Süddeutsche Zeitung (2022), the cost of establishing LNG terminals until Spring 2023 amounted to more than 6.5 billion euros, which is more than twice as much as budgeted after the shutdown of Russian deliveries in August 2022. In the earlier debate on LNG-terminals and prior to constructing Nord Stream 1, German industry and politics decided at the time against the investment of 0.5 billion euros.

In equilibrium, the product market firm may nevertheless not activate dual sourcing and all inputs may be acquired from the monopoly supplier.

Proof Follows directly from the comparison of producer profits in configurations with dual sourcing and single sourcing.

Importantly, dual-sourcing investments are valuable even when (in equilibrium) the option of dual sourcing is not exercised at the delivery stage. The option of accessing world markets is all that is needed to impose price discipline on the supplier and, hence, to insulate the producer from geopolitical risk.

In principle, the costly investments to establish the capacity of dual sourcing could potentially be avoided through long-term delivery contracts, which would eliminate or restrict the supplier's discretionary abuse of market power. However, with severe enforcement limitations especially in a geopolitical context as assumed, such long-term contracts are not time consistent and short-term opportunism attracts the supplier to exert market power.[17]

Welfare: A Role for Economic Policy?

The distortion generated by double marginalization has important implications for national economic policy in a geopolitical context. For example, there might be reasons for the government to take responsibility for the national infrastructure. Specifically, the government, rather than the producing firm, might have proper incentives to invest in infrastructure that secures access to the world market and finance such investments by lump sum tax transfers from national industry. Another policy option could be to subsidize investments associated with establishment of the infrastructure. Both of these options will be briefly analyzed.

Furthermore, a potential role for the government in taxing production ex post in order to curb monopolistic conduct and redistribute rents will be analyzed. While such a tax allows the host country of the producer to limit monopolistic rent seeking of the supplier and to revert some of those rents back to the home country, such a tax policy unambiguously implies lower consumption and consumer surplus. This argument suggests that such a policy should only be adopted, if the domestic firm has failed to establish dual sourcing.

Optimal Subsidy Policy

While limiting prices to the level of world prices, dual sourcing can increase consumer surplus relative to the single sourcing monopoly. Accordingly, dual sourcing enhances efficiency whenever the gains in consumer surplus exceed the investment costs required to guarantee access to the world market. Also, when the condition in

[17] The time-inconsistency of long-term rules or contracts has been a key insight of Kydland and Prescott (1977).

Proposition 1 is not satisfied so that a private producer would not incur the investment, it might be in the interest of society to finance access to the dual source, because dual sourcing generates consumer benefit. Under such circumstances, public infrastructure investments are called for.

Now consider optimal policy for the producing country. Policy attempts to maximize national welfare W, which consists of consumer surplus CS and industry profits Π net of potential infrastructure investment costs, i.e., $W^W = CS^W + \Pi^W - F^W$ in the case of dual sourcing or $W^S = CS^S + \Pi^S$otherwise. With CS^W and CS^S denoting the consumer surplus associated with production under dual sourcing and single sourcing, respectively, regarding the social incentives for public infrastructure investments, the following result applies.

Proposition 2 (Public Infrastructure Investment)

Public infrastructure investments to establish dual sourcing are socially valuable as long as the welfare gain exceeds the investment cost

$$CS^W + \Pi^W - \left(CS^S + \Pi^S\right) = \frac{3}{8b}\left(a - bp^W\right)^2 - \frac{3(a-bc)^2}{32b} < F^W. \tag{1}$$

Public infrastructure investments are needed when the private producer does not find it profitable to invest in access to the dual source, which happens under the following condition:

$$\Pi^W - \Pi^S = \frac{\left(a - bp^W\right)^2}{4b} - \frac{(a-bc)^2}{16b} < F^W. \tag{2}$$

The left-hand side of (1) compares the welfare generated by a product market monopoly operating with the input supplied through dual sourcing with that generated by a monopoly operating with single sourcing. Based on a comparison between (1) and (2), one can directly see that socially optimal incentives for establishing dual sourcing exceed the profit-based incentives because the difference in consumer surplus $CS^W - CS^S = \frac{\left(a-bp^W\right)^2}{4b} - \frac{(a-bc)^2}{32b} > 0$, as long as $p^W < \frac{a+bc}{2b}$. Under such circumstances, the private profit-based incentives for investing in dual sourcing are insufficient. Thus, socially optimal investments in dual sourcing can be implemented either based on public infrastructure investments or based on the design of a subsidy policy to align private incentives with the social optimum.

Consider a proportional subsidy on the infrastructure investment sF^W with $0 \leq s \leq 1$ funded by the consumer via taxes. The subsidy reduces the relevant investment cost facing the producer to $(1-s)F^W$ and, thus, enhances the incentives to invest. The producer will invest, whenever $\Pi^W - (1-s)F^W \geq \Pi^S$. This imposes a lower condition on the subsidy $s \geq \underline{s} = \frac{\Pi^S - (\Pi^W - F^W)}{F^W}$. In addition, the subsidy will also benefit the consumer if $CS^W - sF^W > CS^S$, which implies that $s \leq \bar{s} = \frac{CS^W - CS^S}{F^W}$. Proposition 3 characterizes the subsidy policy which can induce the product market firm to undertake a socially optimal investment in infrastructure.

Proposition 3 (Optimal Subsidy Policy)

The policymaker can induce the product market firm to undertake a socially optimal investment to facilitate access to the world market with a subsidy rate $\underline{s} < s < \overline{s}$, where $\underline{s} = \frac{(a-bc)^2}{16bF^W} - \frac{\left(a-bp^W\right)^2}{4bF^W} + 1$ and $\overline{s} = \frac{\left(a-bp^W\right)^2}{8bF^W} - \frac{(a-bc)^2}{32bF^W}$.

Proof See discussion leading to the Proposition. The maintained assumption $p^W < \frac{a+bc}{2b}$ ensures $\underline{s} < \overline{s}$. □

As in Gehrig and Stenbacka (2023), there are social incentives for the government to subsidize the investment in infrastructure. The subsidy serves as an instrument to facilitate access to the world market for the relationship-specific supplier. This world market access benefits consumers by contributing to supply security against threats of delivery closure on behalf of the relationship-specific supplier.

This analysis has implications for the European natural gas market. In light of the theory, LNG terminals may serve a strategic purpose of limiting ex-post opportunism even when delivering gas by pipeline is more cost efficient.

Ex-Post Taxation

In the present framework, there is no allocative justification for taxing the provision of the final product. Nevertheless, after the Russian supplier dramatically increased prices for natural gas, arguments in the public debate advocated that governments should introduce taxation in order to get a share of the extra rents generated by the supplier's opportunistic conduct. In a sense, this argument refers to an ex-post correction of the supplier's monopolistic conduct in order to divert rents back to the producer's country, whereas infrastructure investment into access to the world market constitutes an ex-ante investment in the prevention of excessive price increases. Next analyze the consequences of an extra per unit tax on the final product.

Consider a tax, τ, on the output price that affects aggregate demand $D(p,\tau) = a - b(1+\tau)p$ and normalize production cost so that $c = 0$. Define (domestic) welfare of the producer's host country in equilibrium by $W(\tau) = \Pi^S(\tau) + CS^S(\tau) + \tau q^S(\tau)$, where $q^S(\tau) = \frac{a-bc}{4}$ is the equilibrium quantity demanded under single sourcing.

Proposition 4 (Proportional Tax)

Consider the case of single sourcing under normalization $c = 0$. With a constant proportional tax $\tau \geq 0$ on the final product, the following results obtain:

a) The supplier's as well as the producer's profits are declining functions of the tax rate τ, i.e. $\frac{\partial \Gamma^S}{\partial \tau} < 0$ and $\frac{\partial \Pi^S}{\partial \tau} < 0$
b) Total welfare is non-monotonic in the tax rate. More precisely

$$\frac{\partial W}{\partial \tau} > 0 \textit{ if and only if } \tau > \sqrt{\frac{3}{4}}\sqrt{\frac{a}{2b}} - 1 = \sqrt{\frac{3}{4}}\sqrt{p^S} - 1.$$

Proof With the constant tax rate τ, we have $\Pi^S = \frac{(a-bc)^2}{16b\ (1+\tau)}$ and $\Gamma^S = \frac{(a-bc)^2}{8b(1+\tau)}$. Hence, the statements of 4(a) follow immediately.

Define $W(\tau) = \Pi^S(\tau) + CS^S(\tau) + \tau q^S(\tau)$. Then $W(\tau) = \frac{3a^2}{32b(1+\tau)} + \frac{a}{4}\tau$ and statement 4(b) follows directly by differentiation. □

According to Proposition 4(a), the tax reduces rents of both firms. In this respect, taxation is an instrument to shift rents not only from the domestic producer, but also from the foreign supplier.[18]

As Proposition 4(b) makes clear, the welfare consequences of taxation of the final good for the country hosting the producer are less obvious. Welfare is a convex, U-shaped function of the tax rate, increasing only for sufficiently high levels of the tax rate and decreasing for low tax rates. This means that the optimal tax rate is determined as a corner solution. With sufficiently elastic demand, the optimal rate is $t^* = 0$ because, under such circumstances, the market disciplines pricing without taxation. With sufficiently inelastic demand, the highest feasible[19] tax rate would be socially optimal. Accordingly, taxation diverts rents back to the producer's country only when consumer surplus is low anyway due to highly inelastic demand. It should again be emphasized that, from an allocative point of view, taxation policy is inferior to a policy which guarantees investment in dual sourcing ex-ante.

Geopolitics

It is tempting to draw some parallels to current geopolitical developments. The basic tensions identified in the present framework do seem to play out in real politics also even though naturally, in the real world, many more stakeholders are involved and objectives get blurred by heterogeneous interests. Nevertheless, it is tempting to discuss the basic tensions and mechanisms in light of our exceedingly stylized theory.

For example, in 2018, Germany imported natural gas via pipelines only but from various suppliers: 57% from Russia, 34% from the Netherlands, and 5% from Norway (IEA, 2020). With the completion of the Nord Stream 2 pipeline, the share of Russian imports would have grown even more in 2022. While there have been multiple suppliers, Russia clearly had a dominant position in supplying natural gas to Germany. What matters in light of our theory is that it was exceedingly costly for Germany to substitute for alternative sources of natural gas or even for alternative providers of energy in the short run, especially since Germany purposefully did not invest in LNG-terminal

[18] The popular demands of introducing windfall taxation on domestic producers benefitting from energy price increases seem to build on precisely this argument (e.g., Baunsgaard & Vernon, 2022).

[19] Feasibility would be determined by factors outside the present model.

capacity prior to February 2022. Only after the start of the Russian war in Ukraine, in line with our stylized model, Germany started investing heavily in LNG terminals.[20]

Also, the long-run strategy of Germany to de-carbonize its energy mix had not yet started properly, since natural gas had been chosen as a bridging technology from the stage of terminating nuclear energy to renewable energy generation, which was still not operating at sufficient scale.[21] In 2022, Germany was caught at a time when substituting away from Russian gas was extremely difficult.

There are further reasons why the real-world situation has been more complex than portrayed in the simple model presented herein. For example, the investment stage consists of two substages: construction of Nord Stream 1 during the first decade of the new Millennium and Nord Stream 2 in the second decade. During the construction phase of Nord Stream 2, delivery of low-cost gas already took place via Nord Stream 1. Only after Nord Stream 2 was completed in January 2022, did the Ukrainian war start (in February) and the Kremlin began interfering with gas delivery to Europe, driving gas prices to astronomical heights.

Overall, the present model tends to underestimate the magnitude of the hold-up problem as the analysis is exclusively concentrated on the abuse of market power with price as the instrument. In response to increased tensions caused by escalation of the war and the associated economic sanctions from the European Union, the Russian supplier of natural gas exploited to an increasing extent its control of the pipeline to limit the flow of natural gas and eventually close down the supply altogether in September 2022.

LNG terminals have been a key issue in German energy policy dating back to at least 2002. The Monopoly Commission (Monopolkommission, 2002) explicitly referred to LNG terminals as a back-stop technology to maintain supply security at a time when the German government preferred to outsource supply security to a highly concentrated private gas industry. In fact, in light of most favorable gas prices from Russia, since the early millennium German gas manufacturers quite effectively lobbied against using liquid gas and invested in the back-stop technology of LNG terminals (Hellwig, 2022a, b).[22]

During the process of constructing the Nord Stream 2 pipeline, LNG terminals served as a bargaining chip with the United States (U.S.) administration in order to prevent the U.S. from sanctioning European companies involved in the construction of the pipeline. The U.S. had always expressed warnings about the predatory character of the investment and the resulting economic dependency on Russia, but the German administration had seen LNG terminals as a toehold of U.S. producers in the German market in order to sell gas produced by fracking. The German political resistance to LNG terminals especially focused on the environmental hazards of fracking in addition to the cost disadvantages relative to Russian pipeline gas. After the change of the U.S. administration in 2020, Germany did not follow up on its commitment of 2018 to establish LNG terminals in order to prevent sanctions.

[20] Other European countries, such as the Baltic states, but also Finland, Spain, Poland and Croatia, had already installed ample LNG capacity before 2022 for their own domestic needs.

[21] Natural gas is an input not only in energy markets, but is also a vital resource for central industries such as the chemical industry, ceramics, glass production and even food stuff.

[22] Prior to the merger with E.On, the company Ruhrgas has been in possession of a license to construct an LNG terminal in Wilhelmshaven since 1979, which was handed back by E.On Ruhrgas in 2009, shortly before Nord Stream 1 was activated in 2011 (Hellwig, 2022b).

The new U.S. government exempted companies involved in Nord Stream 2 from any sanctions even without LNG-terminal investments.

Russia started the war with Ukraine basically at the completion of the Nord Stream 2 pipeline, which is fully owned by the Russian state monopolist Gazprom. Very much in line with the thrust of our current model, in the absence of any second sourcing, Gazprom is still exploiting its monopoly grip on Germany and Europe in order to extract revenues and gain political leverage (e.g., abolishing war-related sanctions). Germany is now forced to invest in secondary sources at a time when such investments in switching suppliers are particularly expensive, both economically and politically. A foresighted and resilient energy policy in line with the recommendation of the monopoly commission (Monopolkommission, 2002) would have avoided the stranglehold, and, thus much reduced the bargaining power and leverage of the state monopolist.[23] In other words, the short-term savings of earlier decades by neglecting investments in resiliency turn into excessively costly investment necessities now in the long-run (Bachmann et al., 2022; Bayer et al., 2022).

How could this happen? Some players in the market may not have been rational and played a game based on the non-credible promises of low prices in the long-run. An alternative explanation could be that, for various reasons, liberal societies applied a much higher discount factor than did autocratic systems.

With such perspective, the short-term savings of German decision makers, including savings from economizing on infrastructure investments, dominate the long-run benefits of dual sourcing, while the autocratic system of the supplier values future rents more highly. In such a setting, the specific outcome could even be interpreted as equilibrium play (in the Nash sense). It is evident that this market outcome is not efficient. This perspective raises questions about the determinants of social discount rates applied to decision-making in different types of societies.

Single Sourcing as an Equilibrium Configuration: A Formalization

This subsection presents a simple two-period extension of the underlying model in order to characterize the conditions under which single sourcing emerges as an equilibrium in a non-cooperative strategic game between countries. While thus far the infrastructure investment of the supplier had already been implemented, now the

[23] A particularity in German competition law allows the Minister of Economic Affairs to overrule the recommendations of the Kartellamt and the Monopoly Commission by Ministerentscheid (Hellwig, 2022a). Because of his earlier employment in the gas industry, Minister of Economic Affairs and Energy Werner Müller (1998-2002) personally felt a conflict of interest and delegated the decision to State Secretary Alfred Tacke (1998-2002). Both Müller and Tacke left the Schröder government after the election of 2002 to take leading positions in the energy Industry, Müller as chief executive officer (CEO) of RAG-AG (2003-7), the follower of Ruhrgas AG, and its successor Evonik (2007-8), and Tacke as CEO of STEAG (2004-6) and Evonik STEAG (2007-8). After the lost election in November 2005, Chancellor Schröder signed the contract for Nord Stream as one of his last actions in office just to chair its supervisory board immediately after quitting office in December. He also became active in Nord Stream 2 (CEO in 2016) and the supervisory boards of Rosneft in 2017 and Gazprom in 2022. As the case of the gas market shows, the instrument of Ministerentscheid opens the door to myopia and short-termism at the expense of resiliency and long-run inconveniences (Hellwig, 2022b).

question will be analyzed, under which conditions such an investment might actually have been undertaken in the first place.

Suppose that infrastructure investments are made in period 1 and sourcing decisions take place in period 2. Further, assume that the relationship-specific supplier (the pipeline supplier) operates with the discount factor δ_S, whereas the domestic government operates with the discount factor δ_W. With single sourcing the condition for the supplier to establish the relationship-specific infrastructure (pipeline) is given by:

$$\delta_S \Gamma^S - F^S = \delta_S \frac{(a-bc)^2}{8b} - F^S > 0. \tag{3}$$

Further, eq. (1) implies that the producing country will not incentivize dual sourcing when

$$\delta_W \left[CS^W + \Pi^W - \left(CS^S + \Pi^S \right) \right] = \delta_W \left[\frac{3}{8b} \left(a - bp^W \right)^2 - \frac{3}{32b} (a-bc)^2 \right] \leq F^W. \tag{4}$$

Now conditions can be derived under which single sourcing will emerge as a subgame perfect Nash Equilibrium.

Proposition 5 (Single Sourcing)

The equilibrium industrial structure will implement single sourcing when the following conditions are satisfied:

$$\frac{\delta_S}{F^S} > \frac{8b}{(a-bc)^2} \text{ and } \frac{\delta_W}{F^W} \leq \frac{32b}{9(a-bc)^2} \ . \tag{5}$$

Proof Condition (4) is equivalent to

$$\delta_W \leq h\left(p^W\right) = \frac{32bF^W}{12\left(a-bp^W\right)^2 - 3(a-bc)^2}.$$

Differentiation with respect to p^W shows that

$$h'\left(p^W\right) = \frac{256b^2\left(a-bp^W\right)F^W}{3\left[\, 4\left(a-bp^W\right)^2 - (a-bc)^2 \,\right]^2} > 0$$

meaning that the function $h(p^W)$ is strictly increasing. This implies that the domestic government has no incentive to establish dual sources whenever

$$\delta_W \leq h(c) = \frac{32bF^W}{9(a-bc)^2}.$$

From this inequality, one can conclude that the combination of conditions (5) characterizes the conditions for the emergence of a single-sourcing equilibrium. □

In a single-sourcing equilibrium, the supplier establishes a relationship-specific infrastructure (pipeline), whereas the domestic government does not undertake any further investments required for dual sourcing. The asymmetric investment constellation constitutes a subgame perfect Nash equilibrium when $\delta_S > \frac{39}{16}\frac{F^S}{F^W}\delta_W$. This implies a high degree of impatience on the producer's side relative to the supplier since typically F^S tends to exceed F^W (substantially).

From (5), the conclusion can be drawn that the combination with a sufficiently high value of the ratio $\frac{\delta_S}{F^S}$ combined with a sufficiently low value of the ratio $\frac{\delta_W}{F^W}$ leads to an outcome consistent with the observations regarding German imports of natural gas. In particular, the combination with a sufficiently patient single-source supplier and a sufficiently impatient domestic government leads to such an equilibrium configuration with single sourcing if the investment required for dual sourcing is sufficiently high relative to the investment required for the relationship-specific infrastructure.

Another potentially complementary reason for seemingly short-sighted producer behavior might emerge due to agency and governance problems. It may appear fair to say that the decisions undertaken in Germany and the resulting lack of resiliency have not been in the best long-term interest of the younger generation.

Concluding Comments

This paper provides an elementary argument for dual sourcing as an investment into supply security. Even when the dual sourcing technology is more costly than the preferred source, it contributes to restraining short-term opportunistic conduct by suppliers with (significant) market power in the long run. This argument holds even when the supply capacities of the dual source are not actively used while in operation. Basically, dual sourcing is a competition-enhancing mechanism that secures delivery of essential resources at reasonable prices even in periods of distress. Moreover, and in addition to providing effective insurance against short-term opportunism and time inconsistency, in such periods of crisis, dual sourcing reduces economical as well as political dependence on suppliers with market power. This seems to be the reason why predatory investments on behalf of the supplier take place only when the producer commits not to invest in alternative channels for market access. The shorter the planning horizon of the producer, the easier it is for a long-term supplier to attract the producer into an exclusive bilateral arrangement with a very high switching cost barrier in the future.

Macroeconomic estimations or assessments of the effects of the Russia-induced energy crisis on German GDP have emphasized the substitution between production factors as decisively important (e.g., Bachmann et al., 2022). As the degree of substitution between Russian natural gas and LNG is particularly high, dual sourcing is precisely an instrument which contributes to minimizing the negative macroeconomic effects of significant price increases or the closing of the natural gas supply. Further, the high degree of substitution also makes predation less attractive to the pipeline supplier in the first place by making recoupment less attractive.

Dual sourcing is also a potential remedy to cope with predatory investments in the field of resource extraction. According to Mailey (2015), predatory investments are typical for state-sponsored monopolists under single-sourcing conditions to extract (rare) resources in resource-rich areas such as Africa. As Mailey highlights, the gains from predatory investments are completely appropriated by the investors and associated corrupted local elites leaving little benefit to the countries.

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