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JEL Classification: D43, H54, L13, L41, L95

Keywords: dual sourcing, Resilience, Switching costs, predatory investments, supply security

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

Thomas Gehrig† Rune Stenbacka ‡

December 2, 2022

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1 Motivation

Outsourcing of production has turned into a popular strategy for creating gains from trade in global markets. However, recently, and especially due to the Covid pandemic and the Russian invasion into Ukraine, the costs of disrupted supply chains have moved into the center of economic discussions. In light of the dramatically increasing geopolitical risks, there is a widespread view that specialization has gone too far. There are calls for refocusing on national production and redesign of globalization as mechanisms to solve supply chain disruptions and enhance welfare (Grossman, Helpman 2022). But is it true that outsourcing is necessarily less resilient than (national) in-house production? Have the risks of specialization been properly accounted for? If not, what would have been proper precautions? Is there a role for investments to secure multiple sourcing?

In this article we argue that on a very basic level resilient production requires investments to avoid or at least reduce strategic risks. Specifically, resilient long-term planning may require costly infrastructure investments such as dual sourcing that limit future opportunistic behaviour of upstream trading partners. Such long-term investments reduce the potentially available efficiencies of outsourcing, but they provide protection against hold-up. Economic policy is well advised to avoid time inconsistencies, meaning that it should not rely on non-credible promises of trading partners.

1.1 The argument in a nutshell

Consider two firms S (supplier) and P (producer), operating at different levels of the supply chain and operating as ”national champions” located in different countries. and a world market for an essential resource. Firm S, located in a country rich on resources, can deliver the input required for crucial production at a price well below the world market price. However, delivering the input to firm P’s production technology requires an infrastructure investment, for example a pipeline. Also access to the world market requires an infrastructure investment into, say, an LNG-terminal. Processing natural gas is cheaper than liquid gas. Accordingly, if both infrastructures were available and gas would sell 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 thought the pipeline. For the purpose 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 all incentives to promise low prices before and during the investment stage, once the pipeline is finished, economic incentives lead S to charge profit maximizing prices. These profit-maximizing prices depend on the prior investments of firm P. If firm P has made adequate investments into LNG-terminals, market power of the supplier S will be limited by the advantage in marginal costs of natural over liquid gas in production. Supplier S will face incentives to price gas just at a level that producer P never finds it optimal to actually use liquid gas in any meaningful quantity. In this case, it appears that the investment in the construction of LNG-terminals has inflicted unnecessary costs. This impression is, however, seriously misleading, because in the absence of 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 the private profits plus welfare in producer P's country by 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 a market price. Dual sourcing can mitigate strategic hold-up risk, 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 a capacity for dual sourcing appears like an insurance premium that 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).

2 Literature

There is a wide range of literature on the phenomenon of outsourcing, which has been an instrumental pillar of globalization (Grossman and Helpman (2005), Grossman et al (2021)). Wheras Grossman et al (2021) focus on general equilibrium models of trade, we follow Shy and Stenbacka (2003, 2005) and others in analyzing the strategic sorucing decisions of the individual firm in a partial equilibrium setting. This allows us to discuss 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) argue in favor of diversification along suppliers. While diversification takes place across firms and industries in their setting, in our framework with strategic risk diversification emerges across infrastructure technologies in otherwise homogeneous 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.[1]

Moreover, the supplier may have strong incentives to invest in the creation of switching costs in order to benefit at the delivery stage. Financing infrastructure investments conditional on the buyer committing not to invest into a dual source is even stronger than switching costs in models of intertemporal price competition with poaching as a mechanism inducing lock-in (e.g. Gehrig and Stenbacka (2004, 2007)). In our setting, dual sourcing can be viewed as an investment in reduction of switching costs in order to facilitate (potential) competition, whereas Gehrig and Stenbacka (2004) characterize equilibrium strategies that increase switching costs in order to relax competition of product markets.

In light of the perspective provided in this paper, dual sourcing can be viewed as analogous to a real option[2] to secure alternative delivery channels. In the absence of extrinsic uncertainty, in equilibrium it will never be exercised. As such it resembles the solution to the hold-up problem of Nöldeke and

[1] There is a related literature on the long-run costs of outsourcing in a R&D-context. E.g. Reitzig et al (2010) argue that outsourcing may seriously affect the knowledge base of innovators in the long-run. Implicitly, also their argument relies on a stochastic context with long-run risk.

[2] Alvarez and Stenbacka (2007) and Van Mieghem (1999) apply a real options approach to characterize the optimal organizational mode, in particular the effect of market uncertainty on the optimal proportion of production based on outsourced inputs. Of course, strictly speaking, our model does not capture exogenous uncertainty

Schmidt (1995). Whereas in the classical hold-up problem the investors might not undertake an efficient investment, in our setting the investor might be tempted to avoid the technologically inferior investment, which will nevertheless not be actively used in equilibrium. But in the absence of such investments the investor runs the risk that all the gains from trade will be captured by the input supplier.

Inderst (2008) demonstrates theoretically that single sourcing is not optimal for a buyer facing suppliers with a sufficiently convex costs unless the buyer has sufficiently strong market power. Du et al (2006) as well as Stenbacka and Tombak (2012) present arguments for dual sourcing based on considerations related to bargaining power. More precisely, they present a model where dual sourcing is an organizational mechanism to balance cost advantages from outsourcing against associated increases in a subcontractor's bargaining power. Yang et al (2012) study the strategic arguments for dual sourcing when facing suppliers with private information regarding the probability of delivery disruption.

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

3 The Framework

Consider a world with two commodities, a final product and an essential resource required for final production. Generation of the essential resource takes place at a different geographical location and in a different country than the production of the final good. Hence the essential resource needs to be transported to the producer. It is not possible to produce the commodity directly at the source of the essential resource. An intriguing example could be the production of heat by means of burning gas. It is far more economical to transport gas long distances than heat.

Transportation Infrastructure The resource can be transported with at least two different technologies. One technology connects to the world market like a harbour 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, including the investment to build an LNG terminal, but it secures access to delivery of the input at the world market price p^W.

The alternative is a supplier-specific technology like a pipeline from the supplier directly to the producer. This technology is 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 into a bilateral monopoly configuration. We assume the construction of the pipeline to impose no costs on the producer P in the final goods market. [3]

In principle, also the supplier could invest into the technology giving access to the world market, which would allow selling supply at world market prices, or below. We will sidestep the possibility since we are interested in configurations where the supplier initially sells deliberately at privileged prices below world market as part of strategy to exploit market power during a subsequent recoupment phase directed to locked-in customers.[4]

Market Structure The producer enjoys a downstream monopoly and faces a demand function $D(p)$. The producer buys the input either at the world market at price p^W and/or from the supplier at p^S and charges product market price p in order to maximize profits.

The foreign supplier S can produce the essential resource at a cost c well below the world price $c < p^W$. A key question to be analysed 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 our 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, we will also 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. In this channel the supplier has complete discretion on prices and can change them whenever opportune.

[3] Such an assumption is consistent with, for example, the observation that Gazprom funded and owns the Nord Stream 2 pipeline.

[4] Such a focus seems justified for capturing, for example, Russian delivery of natural gas to Germany. In this case initially favorable delivery terms were subsequently followed by significant price increases and even closing of supply of natural gas as a step in the escalation of events following Russia's military attack on Ukraine.

While it is illustrative to differentiate supplier and producer geographically, an alternative, but equivalent, interpretation would differentiate between the production modes of in-house production (instead of world market) and outsourcing to a potentially more efficient external subcontractor. With such an interpretation, the establishment of in-house capability is an effective strategy to limit exploitation of market power by the subcontractor with a monopoly position.

Sequence of Decisions We consider a three-stage game. In the first stage the producer decides about the infrastructure investments, which are long-term strategic decisions. At stage two the supplier decides about the delivery prices p^S and at stage three the monopolist will sell the final product to the market at a profit-maximizing uniform price p.

1. Infrastructure choice: 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 terminals for liquefied natural gas, 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 the decision regarding infrastructure of delivery has been made, prices are determined. The supplier-specific prices can be modified at short term in a discretionary way. In contrast, potential changes of infrastructure investments at a later time would require significant extra expenses and implementation time.

4 The Analysis

4.1 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:

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

where $r = p^W$ in case delivery of the marginal unit takes place by 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

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

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

4.2 Supplier Pricing and Profit

4.2.1 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

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

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

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

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

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

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.[5]

4.2.2 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, we assume 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 the circumstances characterized above the supplier's equilibrium revenues are lower than those under single sourcing:

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

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 than those of the supplier. Further, the output market producer's equilibrium revenues associated with dual sourcing exceed those associated with single sourcing[6]:

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

[6] Since the establishment of dual sourcing includes fixed investment costs for infrastructure, whereas the we have assumed the input supplier to bear the costs of infra structure with single sourcing the comparison is unclear as far as equilibrium profit is concerned.

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

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. Next we analyse the technology choice in the first stage.

4.3 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.[7] The question, however, 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. And 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 into a dual sourcing technology. However, such promises are not credible, as time consistent behaviour defines a temptation to raise prices to the profit-maximizing level after investments have been made. As established in Section 4.2, 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 for S to implement predation. In this predation strategy the recoupment is importantly based on the fact that the producer's investment in dual sourcing is much more expensive ex-post, once S has increased its price to exploit its market power. An important element of those cost increases is time: the faster S needs to build the infrastructure for dual sourcing, the more costly will be the required investment. This feature is well

[7] In this sense it is not by chance that Nord Stream 2 has been fully owned by Gazprom.

illustrated by the costs and difficulties for Germany associated with the establishment of LNG-capacity[8] in response to Gazprom's price increases and subsequent close-down 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)

Let $p^W > c$. Then dual sourcing will emerge in equilibrium if and only if

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

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 the configurations with dual sourcing and single sourcing. □

Importantly, the 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.

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, such long-term contracts are not time consistent and short-term opportunism attracts the supplier to exert market power.[9]

[8] According to *Süddeutsche Zeitung* (2022) the cost of establishing LNG-terminals until Spring 2023 amounts to more than € billion 6.5, which is more than twice as much as budgeted after the shut down of Russian deliveries in August. 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 € billion .5.

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

5 Welfare - A Role for Economic Policy?

The distortion generated by double marginalization have 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 the 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 the investments associated with the establishment of the infrastructure. We briefly analyse both of these options.

Furthermore, we analyse a potential role for the government in taxing production ex post in order to curb monopolistic conduct and redistribute rents. 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.

5.1 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. But also, when the condition in 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.

A crucial feature of our analysis is that $p^W > c$. Without loss of generality we impose the normalization $c = 0$. With CS^W and CS^S denoting the consumer surplus associated with production under

dual sourcing and single sourcing, respectively, we formulate the following result regarding the social incentives for public infrastructure investments.

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

$$CS^W + \Pi^W - (CS^S + \Pi^S) \;=\; \frac{3}{8b}(a - bp^W)^2 - \frac{9a^2}{128b} \;>\; F^W. \tag{1}$$

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

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

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) we can directly see that socially optimal incentives for establishing dual sourcing exceed the profit-based incentives because the difference in consumer surplus $CS^W - CS^S \;=\; \frac{(a-bp^W)^2}{8b} - \frac{a^2}{128b} \;>\; 0$, which holds true if and only if $p^W \;<\; \frac{3a}{4b}$. 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.

Our analysis is conducted under the assumption that the world market imposes competitive discipline on supplier-specific delivery, which is captured by the assumption $p^W < \frac{a+bc}{2b}$. This assumption implies that $CS^W - CS^S \;>\; 0$. In the Appendix we we characterize the subsidy rate such that the private firm would adopt dual sourcing precisely for those world market prices p^W when the practice of dual sourcing is socially optimal. We formulate this characterization in the following Proposition.

Proposition 3 (Optimal Subsidy Policy)

If $CS^W - CS^S < F^W$ *the subsidy rate s defined by the condition*

$$s = \frac{CS^W - CS^S}{F^W} \tag{3}$$

is socially optimal as it aligns the private incentives for adoption of dual sourcing with the social ones. If $CS^W - CS^S \geq F^W$ *it is socially optimal for the government to bear the full costs of investment in the infrastructure to facilitate dual sourcing.*

Proof: See Appendix. □

As in Gehrig and Stenbacka (2022), there are social incentives for the government to subsidize the investment in infrastructure. The subsidy serves as an instrument to force the relationship-specific supplier to meet the price of the world market to the benefit of consumers. By facilitating access to the world market the subsidy also contributes to supply security against threats delivery closure on behalf of the relationship-specific supplier.

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

5.2 Ex post Taxation

In our 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 an access to the world market constitutes an ex-ante investment in the prevention of excessive price increases. Let us next analyse the consequences of an extra per unit tax on the final product.

Consider a proportional tax on the output price that affects aggregate demand $D(p,t) = a - b(1+\tau)p$. As in the previous subsection, we let $c = 0$. Moreover, define (domestic) welfare of the producer's host country in equilibrium by $W(\tau) = \Pi^S(\tau) + CS^S(\tau) + \tau q^S$, where $q^S(t) = \frac{a}{4}$ is the equilibrium quantity demanded under single sourcing.

Proposition 4 (Proportional Tax)

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

(a) The supplier's profit as well as the producer's profit are declining functions of the tax rate τ, i.e. $\frac{\partial \Gamma^*}{\partial \tau} < 0$ and $\frac{\partial \Pi^S}{\partial \tau} < 0$.

(b) Total welfare is non-monotonic in the tax rate. More precisely,

$$\frac{\partial W}{\partial \tau} > 0 \quad \textit{if and only if} \quad \tau > \sqrt{\frac{9a}{32b}} - 1 = \frac{3}{4}\sqrt{p^S} - 1.$$

Proof: See Appendix.

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.[10]

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, being 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 $\tau^* = 0$, because under such circumstances the market disciplines pricing without taxation.

[10]The popular demands of introducing windfall taxation on domestic producers benefiting from energy price increases seem to build on precisely this argument.

With sufficiently inelastic demand the highest feasible[11] 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. When demand is sufficiently elastic, and consumer surplus sufficiently large in consequence, the optimal tax rate is $\tau = 0$.

It should again be emphasized that from an allocative point of view the taxation policy is inferior to a policy which guarantees the investment in dual sourcing ex-ante.

6 Geopolitics

It is interesting to draw some parallels to current geopolitical developments. The basic tensions identified in our framework do seem to play out also in real politics even though, naturally, in the real world many more stakeholders are involved and objectives get blurred by heterogeneous interests.

It is tempting to discuss the basic tensions of the German gas market in light of our theory. Naturally, the real world situation has been more complex than the simple model. For example, the investment stage consists of two substages, the 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 had been completed in January 2022 the Ukrainian war started in February and the Kremlin began interfering with gas delivery to Europe, driving gas prices to astronomical heights.

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

The issue of LNG-terminals has been a key issue in German energy policy dating back to at least 2002. The Monopoly Commission (Monopolkommission 2002) has explicitly referred to LNG-terminals

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

as a back-stop technology to secure 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 investing into the back-stop technology of LNG-terminals (Hellwig, 2022a and 2022b).[12]

During the process of constructing the Nord Stream 2 pipeline LNG-terminals served as a bargaining chip with the US administration in order to prevent the US from sanctioning European companies involved in the construction of the pipeline. The US 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 US 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 US administration in 2020 Germany did not follow up its commitment of 2018 to establish LNG-terminals in order to prevent sanctions. The new US 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 time of completion of the Nord Stream 2 pipeline, which is fully owned by the Russian state monopolist Gazprom. And very much in line with the thrust of our 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 to gain political leverage, e.g. in abolishing war-related sanctions. Germany is now forced to invest in secondary sources at a time when such investments into 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.[13] In other words, the short-term savings of earlier decades by neglect-

[12] Prior to the merger with EON the company Ruhrgas was in a possession of a License to construct a LNG-terminal in Wilhelmshaven since 1979, which was handed back by EON Ruhrgas in 2009 shortly before Nord Stream 1 was activated in 2011 (Hellwig, 2022b).

[13] 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 2022). 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

ing investments in resiliency turn into excessively costly investment necessities now in the long-run (see Bachmann et al. 2022, Bayer et al. 2022).

How could this happen? Either some players in the market were not rational and did play 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 apply a much higher discount factor than autocratic systems. With such a perspective the short-term savings of German decision makers, including the savings from economizing on the infrastructure investments, dominate the long-run benefits of dual sourcing, while the autocratic system of the supplier values more highly future rents. In such a setting the specific outcome could even be interpreted as equilibrium play (in the sense of Nash). It is evident that this market outcome is not efficient. This perspective raises the question about the determinants of the social discount rates applied for decision-making in different types of societies.

6.1 Single Sourcing as an Equilibrium Configuration: A Formalization

In this subsection we design a two-period extension of our model in order to characterize the conditions under which single sourcing emerges as an equilibrium in a non-cooperative strategic game between countries.

Suppose that the infrastructure investments are made in period 1 and that the sourcing decions 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

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 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 for Nord Stream 2 (CEO in 2016) and the supervisory boards of Rosneft (2017) and Gazprom (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. See also Hellwig (2022b).

$$\delta_S \Gamma^S \; - \; F^S \;\; = \;\; \delta_S \frac{a^2}{8b} \; - \; F^S \;\; > \;\; 0, \tag{4}$$

where we have made use of the normalization $c = 0$. Further, from (1), the condition for dual sourcing not to induce a welfare gain under similar circumstances is given by

$$\delta_W \; [CS^W + \Pi^W - (CS^S + \Pi^S)] \;\; = \;\; \delta_W [\frac{3}{8b}(a - bp^W)^2 - \frac{9a^2}{128b}] \; - \; F^W \;\; \leq \;\; 0. \tag{5}$$

In the Appendix we show that the combination

$$\frac{\delta_S}{F^S} \;\; > \;\; \frac{8b}{a^2} \;\; \text{and} \;\; \frac{\delta_W}{F^W} \;\; \leq \;\; \frac{128b}{39a^2} \tag{6}$$

implies an equilibrium configuration such that the single source supplier establishes the relationship-specific infrastructure (pipeline), whereas the domestic government does not undertake the investment required for dual sourcing.

From (6) we can draw the conclusion 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.

We might add further potentially complementary reasons for seemingly short-sighted producer behaviour such as agency and governance problems. It may appear fair to say that the decisions undertaken in Germany and the resulting lack of resiliency may have not been in the best interest of the young generation.

7 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 takes 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 (see, for example, 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 closing of supply of natural gas. 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.

8 Appendix

Proof of Proposition 3:

We define the function

$$f(p^W) \;=\; CS^W + \Pi^W - (CS^S + \Pi^S) \;=\; \frac{3}{8b}(a - bp^W)^2 - \frac{9a^2}{128b}. \tag{7}$$

This function is strictly decreasing as a function of p^W. In light of (1) the criterion of welfare maximization dictates that there is an incentive to establish dual sourcing when $p^W \leq p^{W,W}$, where $p^{W,W}$ is defined by $f(p^{W,W}) = F^W$. Further, we define the function

$$g(p^W) \;=\; \Pi^W - \Pi^S = \frac{(a - bp^W)^2}{4b} \;-\; \frac{a^2}{16b}\,, \tag{8}$$

which is also strictly decreasing as a function of p^W. Further, it holds true that $f(p^W) \;>\; g(p^W)$ for all values of the world market price p^W. With a socially optimal subsidy policy, profit incentives leads the firm to adopt dual sourcing precisely when $p^W \leq p^{W,W}$. This is realized for a subsidy rate satisfying $g(p^{W,W}) = (1-s)F^W$. This will be implemented with a subsidy rate satisfying

$$CS^W \;-\; CS^S \;\;=\;\; s\,F^W. \tag{9}$$

Clearly, if $CS^W - CS^S \;\geq\; F^W$ condition 9 violates feasibility as it would call for a subsidy rate exceeding one. Under such circumstances the optimal policy would be for the policymaker to bear the full costs of the investment required to facilitate dual sourcing.

Proof of Proposition 4:

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

Define $W(t) = CD^S(\tau) + \Pi^S(\tau) + \tau q^S$.

Then

$W(\tau) = \frac{9a^2}{128b(1+\tau)} + \tau\frac{a}{4}$

and statement b) follows directly by differentiation.

Derivation of (6):

Condition (5) is equivalent to

$$\delta_W \;\leq\; h(p^W) \;=\; \frac{8bF^W}{3(a-bp^W)^2 - \frac{9}{16}a^2}.$$

Differentiation with respect to p^W shows that

$$h'(p^W) \;=\; \frac{48b^2(a-bp^W)F^W}{[3(a-bp^W)^2 - \frac{9}{16}a^2]^2} \;>\; 0\,,$$

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

$$\delta_W \;\leq\; h(0) \;=\; \frac{128bF^W}{39a^2}.$$

Combination of this with (6) leads us to the conclusion that the combination of conditions (6) characterizes the conditions with single sourcing as the equilibrium.

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