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The Impact of the 2022 Oil Embargo and Price Cap on Russian Oil Prices*

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Abstract

This paper documents the effect of the oil embargo and price cap on Russian oil exports in the wake of the Russian invasion of Ukraine in February 2022. We show that the embargo forced Russia to accept a $32/bbl discount on its Urals crude in March 2023 relative to January 2022, nearly half of which is directly attributable to the higher cost of shipping crude oil over longer distances, as Russia diverted much of its crude oil exports to India. Based on a calibrated model of global oil supply and demand, the remainder ($17/bbl) can be explained by increased Indian bargaining power. We also provide a similar analysis for the ESPO price discount on exports to China. In contrast, the price cap deprived Russia of the financial resources it spent on assembling a “shadow” fleet of tankers, but its effect on the Russian oil export price was negligible once the adoption of the price cap had facilitated the use of Western services to transport Russian oil to Asia.

Keywords: Russia, Oil, Sanctions, Embargo, Price cap

JEL Codes: F51, Q41, Q48

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1 Introduction

The Russian invasion of Ukraine in February 2022 prompted widespread voluntary restrictions on imports of Russian crude oil, which were replaced by a formal oil embargo in December 2022 and a cap on the fob price of Russian crude oil sold to countries not participating in the embargo.[1] The embargo, led by the U.S. and the European Union, dramatically reduced demand for Russian oil from traditional buyers, and caused global oil trade flows to be redirected. The main effects of the voluntary restrictions and the subsequent formal embargo were twofold. First, by segmenting the market into buyers and non-buyers of Russian oil it increased the distance Russian oil was required to travel to reach the market and hence the transportation cost. This, in turn, created scarcity in the tanker market that raised the cost of shipping oil by sea for a given distance. Second, the embargo also raised the bargaining power of India and China, the two remaining buyers large enough to absorb large quantities of Russian oil.

The price cap that was added by the G7 countries served both economic and political objectives. Importantly, it allowed the West to relax the ban on using Western shipping insurance and related financial services to transport Russian oil to third countries, which had been envisioned in the EU's 6th sanctions package and was scheduled to go into effect in 2023. The fear was that this maritime services ban would cause a surge in global oil prices and a global recession. The price cap on Russian oil exports appeased hardliners in Europe calling for tough sanctions, while ensuring the flow of Russian oil to countries not participating in the embargo. Its objective was to allow countries not participating in the oil embargo to purchase Russian oil, while making it more difficult for those countries to import Russian crude valued above the price cap by restricting access to Western maritime services. Although the initial price cap of $60 per barrel was intended to be adjusted periodically, as of early 2025, the cap has remained at $60, even as the global price of oil retreated from its high in mid-2022.

A question of obvious policy interest is whether the embargo and/or the price cap reduced Russian oil export revenues or diverted Russian resources away from the war effort, and how this outcome was achieved. In this paper, we provide the first quantitative analysis of the economic channels through which these sanctions operate. Quantifying these channels empirically is complicated by the very limited data available about Russian oil trade and about the prices received by Russia and paid by importers of Russian oil. This dearth of data prohibits the use of standard empirical models. We show that the data nevertheless suffice to gauge the impact of

[1] The fob ("free on board") price of oil is what the seller receives per barrel sold. This excludes the cost of insuring and transporting the oil, which is borne by the buyer and, along with the cost of the oil itself, comprises the cif ("cost, insurance and freight") price.

the sanctions on Russian oil prices and oil revenues.

Our analysis distinguishes between the effects of the import restrictions and of the price cap. We document three key facts. First, the decline in Russian oil export revenues since January 2022 was achieved by reducing the Russian fob price of oil rather than the volume of Russian oil exports. Second, we estimate that roughly half of the Russian price discount arose from having to redirect Russian oil exports to more distant destinations. We find no evidence that the tanker insurance premium arising from the Ukraine war and the G7 price cap was quantitatively important. Third, we calibrate a model of global oil supply and demand to demonstrate that the remainder of the increased Russian price discount can be explained by a modest increase in Indian and Chinese market power due to the segmentation of the oil market. We provide tentative empirical support that India has market power in the Urals market, consistent with coordination by the state-owned Indian Oil Corporation.

Previous explanations of the increased price discount relative to Brent centered on the possibility of Russian companies gaining access to Western insurance by nominally satisfying the price cap, while overcharging customers for the transportation of the oil, allowing companies to recuperate lost revenue (e.g., Cook et al. (2023)). Not only is there no direct evidence supporting this view, but it leaves unexplained why the Russian fob price of Urals oil would have fallen well below the price cap in early 2023. Our analysis shows that there is an alternative explanation that explains this fact and that does have some empirical support.

Our conclusions are also at odds with common perceptions in the literature about the efficacy of the price cap in reducing Russian oil revenues. Theoretical conditions under which the price cap would stabilize global oil prices while reducing Russian oil revenues are outlined in Johnson et al. (2024). These include the presence of an effective enforcement regime to ensure compliance by the global tanker fleet, and the absence of a so-called "shadow fleet" of oil tankers that can operate at scale outside of the scope of the price cap. More recent theoretical work by Cardoso et al. (2024) that incorporates the endogenous emergence of a shadow fleet also highlights the importance of enforcing the price cap. We present evidence that, as of 2024, these conditions had not been met.[2] We are not saying that the economic outcomes in 2023 would have been the same if the price cap had never been implemented. Indeed, we agree that the price cap helped avert a potentially large surge in the price of oil and a global slowdown by relaxing the EU maritime services ban. Having accomplished this objective, however, the price cap effectively had served its purpose and did not materially contribute to the Russian fob price discount in 2023. In particular, once the

[2]On January 1, 2025, the U.S. Treasury announced a major new enforecement initiative, acknowledging that previous enforcement efforts had been insufficient.

Russian fob price fell below the price cap in the first half of 2023, whether the price cap was enforced or not made no difference for the economic outcomes. Nor did the price cap prevent the average Russian fob price from rising above the price cap on the Pacific coast throughout 2023, or from the Black Sea and Baltic Sea in the second half of 2023.

This paper contributes to several strands of the literature. Our estimates of the effects of recent sanctions on Russian oil contribute to a growing literature on the economic costs of sanctions on countries initiating these sanctions (or "senders"), as in Besedeš et al. (2021), and on countries being targeted (see, e.g., Ahn and Ludema (2020) on "smart sanctions"). Our quantitative analysis of the price cap on Russian oil revenue builds on a recent theoretical work on how price caps can be used as a sanctions tool (e.g., Johnson et al. (2024), Cardoso et al. (2024)). Our conclusion that the price cap had little direct effect on the Russian fob price, but was important primarily because it persuaded the EU to abandon its general ban on maritime services for the transport of Russian oil, is consistent with the distinction between economic and political outcomes described in Felbermayr et al. (2021).[3] By documenting the importance of the transportation sector in resolving price differentials, we complement Borenstein and Kellogg (2014), Kellogg and Sweeney (2023), and Brancaccio et al. (2020), among others. In addition, we contribute to a literature quantifying the genesis and effects of supply and demand shocks in the global oil market (e.g., Kilian and Murphy (2014)). Finally, our paper complements a recent empirical literature documenting the evolution of Russian oil export volumes, export prices and price discounts in considerable detail (e.g., Hilgenstock et al. (2023)). We not only expand on this literature in several directions, as required by our analysis, but - unlike earlier empirical studies - we focus on explaining the evolution of these data through the lens of economic models. [4]

The remainder of the paper is organized as follows. Section 2 documents how Russian crude oil exports and revenues have evolved since the invasion of Ukraine and

[3]These and other studies in the sanctions literature are summarized in Morgan et al. (2023).

[4]Hilgenstock et al. (2023) laid the groundwork for research on the effects of the oil embargo and price cap. It is important to stress the dimensions in which we add to their important contributions. While we draw on some of their empirical results, the overlap between our own descriptive analysis in Sections 2 and 3 and the analysis in Hilgenstock et al. (2023) is minimal. Not only do we focus on different features of the data, but we use different data sources and incorporate more recent data than Hilgenstock et al. (2023). Another key difference is that, whereas their analysis is purely descriptive, our main contribution is to explain *why* the Russian fob price discount changed in March 2023, to identify and quantify its economic determinants, and to quantify the respective contributions of the embargo and price cap. Moreover, whereas Hilgenstock et al. (2023) conjecture that the G7 price cap may have been ineffective, we formally show using novel data and modeling that its imposition did not have important effects on the Russian fob price. Finally, while we are in agreement with Hilgenstock et al. (2023) that oil import restrictions reduced Russian revenues, we show that the extent of the fall in oil revenues - after controlling for fluctuations in global demand and supply unrelated to the embargo and price cap - is quite different from that reported in Hilgenstock et al. (2023) and by the U.S. Treasury.

shows that the evolution of Russian oil revenues has been driven by the fob price. Section 3 documents the evolution of the Russian fob price discount and describes how this discount changed as the oil embargo and oil price cap were imposed. In Section 4 we discuss how and to what extent rising transportation costs contributed to the Russian fob price discount, and we quantify the residual increase in this discount left unexplained by higher transportation costs. In Section 5, we propose a novel explanation of this residual. We stress that the market segmentation caused by the oil embargo endowed the only remaining large buyers of Russian oil with monoposony power, allowing them to further lower the Russian fob price. We present a calibrated model of global oil supply and demand that allows us to quantify each of the economic determinants of the price discount at which Russian oil trades in global markets. The model demonstrates that a modest degree of Chinese and Indian market power can explain the remainder of the Russian oil price discount. We provide tentative empirical evidence based on Indian cif prices that is consistent with the existence of nontrivial market power in the Urals market. Section 6 addresses the alternative view that most, if not all, effects of the price cap materialized in 2022, reflecting the anticipation that the price cap would work. The concluding remarks are in Section 7. Section 5

2 Key Stylized Facts

Before building a model of the impact of the sanctions, it is necessary to understand the evolution of Russian oil trade and revenues since the invasion of Ukraine in early 2022. In this section, we provide a comprehensive assessment of the relevant facts, including an examination of the effects of the sanctions on Russian oil revenues. We also discuss the shadow fleet and the relationship between the oil prices that are relevant for our analysis.

January 2022 is a good starting point not only because it marks the point at which detailed monthly data for Russian oil exports and revenues become available, but also because at that point the risk of a Russian invasion still seemed low, so anticipatory effects of the invasion of Ukraine that took place in late February 2022 are not likely to be important.[5] As of January 2022, Russian crude oil exports involved pipeline exports to China and to Western Europe, as well as seaborne exports, mainly from

[5]It was not that the Russian military build-up went unrecognized by Ukraine and the West, but that such build-ups were by no means unprecedented and could be interpreted as a bargaining tool designed to exert political pressure. In January, U.S. efforts still focused on de-escalation and deterrence. It was only in mid-February that the U.S. and other countries urged their citizens to leave Ukraine immediately, as the readiness of Russian forces increased. This interpretation is also supported by the evolution of the oil price uncertainty index developed in Kilian et al. (2024), which only surges in March 2022.

ports in the Baltic Sea, the Black Sea and the Sea of Japan. In response to Russia's invasion of Ukraine in late February 2022, many countries curtailed their sea-borne imports of Russian crude oil. This happened well before the oil embargo and oil price cap were imposed in December 2022 (see Figure 1). As most European countries, the United States, Japan and South Korea reduced their seaborne imports from Russia, other countries including notably India, China and Turkey took advantage of the availability of Russian oil at discounted prices and substantially increased their seaborne imports of Russian crude.[6]

India became the primary destination for Russian seaborne crude exports with Indian imports from Russia nearly three times China's seaborne imports in March 2023. India's low-cost imports from Russia partially substituted for higher-cost crude imports from the Middle East, West Africa and the United States, but mainly constituted additional Indian demand. Indian imports in part reflected an arbitrage opportunity whereby discounted crude from Russia is processed by Indian refineries and re-exported as refined products to the rest of the world at global prices, and in part allowed India to satisfy growing domestic demand. This caused the volume of Russian seaborne crude oil exports to India to increase markedly from January 2022 to March 2023 – and to persist at that level later in 2023.[7]

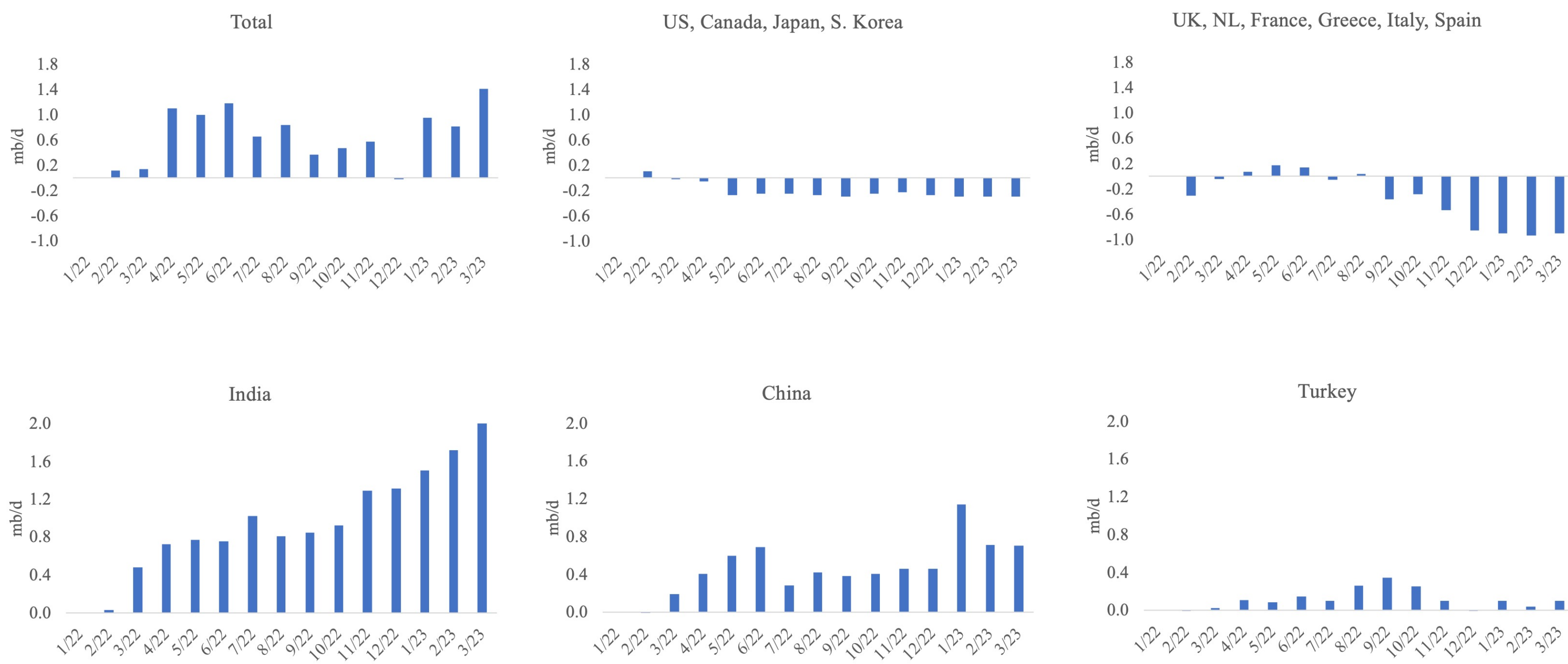
2.1 The evolution of Russian crude oil exports since January 2022

Russia not only successfully diverted its seaborne exports from Europe to Asia, but it also managed to offset the reduction in its pipeline oil exports to Europe, especially with the onset of the oil embargo. There is no question that the volume of Russian oil exports did not decline in the year following the invasion of Ukraine. In fact, according to our calculations, the overall volume of Russian crude exports increased within this time frame. Thus, the primary effect of the Russian invasion of Ukraine has been a redirection of oil trade flows rather than a reduction in oil trade.

[6] In the case of China, these imports occurred on top of existing commitments to import Russian crude oil by pipeline. Because exports to China by pipeline were capacity constrained and therefore did not change much, the increase in China's seaborne imports or Russian crude captures the change in overall Chinese imports.

[7] The dip in Russian oil exports in December 2022 reflected unusually harsh weather at Russian ports in East Asia rather than the effect of sanctions.

Figure 1: Russian crude tanker exports relative to January 2022 by key destinations (mb/d)

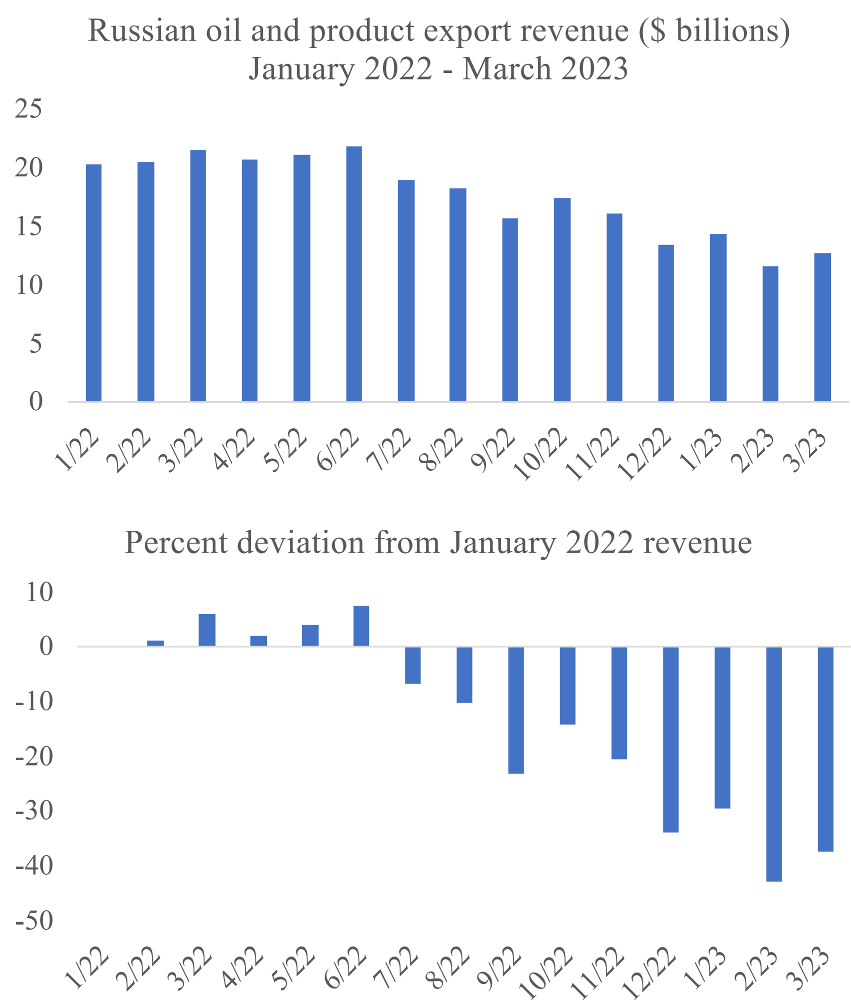


Source: TankerTracker.com and authors' calculations. Data from January 2022 through March 2023 normalized relative to January 2022 level, the month before the Russian invasion of Ukraine. All data shown are revised data as of May 2023, so cargoes with unknown destinations are largely accounted for.

2.2 The evolution of Russian crude oil revenues since January 2022

Policymakers have pointed to the fact that Russian oil and refined product export revenues in early 2023 were about 40% lower than before the invasion as evidence that the price cap is working (e.g., Rosenberg and Van Nostrand (2023)). Figure 2 shows that indeed the combined revenue from Russian crude oil and refined product exports by February 2023 had declined 43% below its January 2022 level, which is lower than in any previous month since the invasion started. It is important, however, to put this decline into context.

Figure 2: Russian export revenue from crude oil and product exports since January 2022



Source: IEA OMR and authors' calculations

First, much of this price decline predated the imposition of the formal embargo and price cap. The incremental decline in Russian oil revenues in December 2022 was only 15% compared to November 2022, arguing against an important incremental role for the formal sanctions. While the announcement of a possible price cap in June 2022 might have caused oil revenues to decline in anticipation of these sanctions, we will show in Section 6 that empirical evidence does not support this view.

Second, while the oil embargo only affects Russian crude oil exports, the price cap applies to Russian crude oil exports starting in early December 2022 and Russian exports of refined products starting in February 2023, with shipments already in transit exempted. Thus, for the purpose of our analysis, it makes sense to analyze Russian crude oil exports separately from exports of refined products.

Third, some of the observed decline in Russian oil revenues may simply reflect the decline in global oil prices, as global demand weakened in the second half of 2022. Conversely, the surge in oil prices in the first half of 2022, which was already well underway before the invasion, clearly helped raise Russian oil revenues. This makes it harder to determine how effective the policy response to the invasion of Ukraine has been.

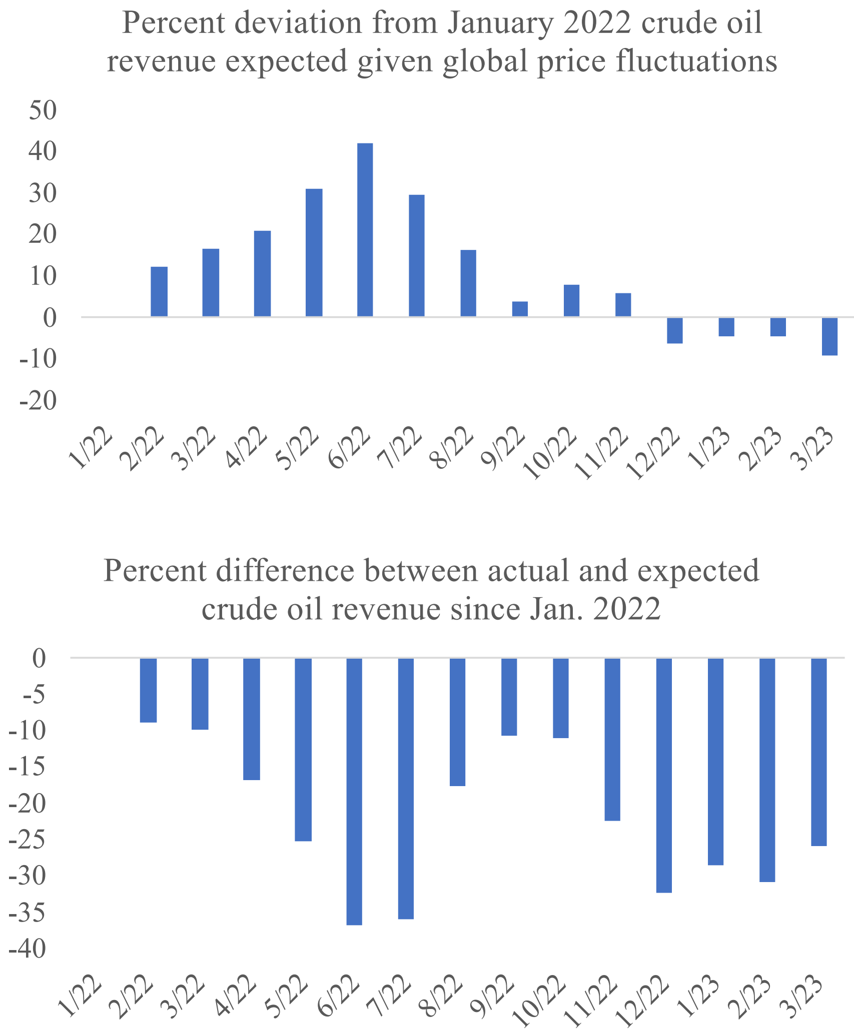
Figure 3 seeks to control for unrelated variation in the Russian export price of oil by constructing a counterfactual that holds constant the crude oil export volume at its January 2022 level, while extrapolating the Russian fob price of crude oil at the rate of growth of the spot price of Brent crude oil. The latter price is a widely used benchmark for the global price of crude. A strong case can be made that the evolution of the Brent price since mid-2022 mainly reflected fluctuations in global oil demand as well as oil supply decisions by oil producers other than Russia (see Section 6.1). To account for the temporary surge in the Brent price in March 2022, which was arguably driven by concerns that Russia might withhold its oil from the global market, we remove this price spike from the Brent price series by linear interpolation. There is no indication that these concerns persisted beyond March (see Kilian et al. (2024)).

The upper panel of Figure 3 shows the evolution of Russian oil export revenues expected given the evolution of the global price of crude oil in the absence of the war. Allowing Russian exports to increase over time would not change this picture fundamentally.[8] The lower panel plots the difference between the actual Russian revenues from seaborne exports of crude oil in each month and the revenues expected even in the absence of any sanctions or voluntary import restrictions, given this path of the global price of oil.

Most importantly, from our point of view, Figure 3 illustrates that the effectiveness

[8]In constructing this counterfactual, we ignore possible seasonality in Russian oil exports over the course of the year because this seasonality is difficult to estimate based on the available limited monthly historical data for Russian seaborne oil exports.

Figure 3: Russian export revenue from crude oil since January 2022 controlling for global oil price fluctuations



Source: IEA OMR, Argus, Platts, Clipper, Bloomberg, Kpler and authors' calculations. We hold constant the volume of Russian oil exports in January 2022 and extrapolate the Russian fob price at the rate of growth of the Brent spot price after removing the price spike in March 2022 by linear interpolation.

of the sanctions, as measured by oil revenues, reached its maximum already in June 2022 rather than in early 2023. The informal sanctions imposed right after the invasion of Ukraine were quite effective at reducing Russian revenues before being relaxed somewhat in the second half of 2022, perhaps in anticipation of a formal embargo. Voluntary import restrictions of selected countries alone created revenue shortfalls as large as 36% in mid-2022, compared to 32% in December 2023. Moreover, compared to November 2022, the average shortfall increased by only 7 percentage points on average after the formal oil embargo and price cap were imposed. This contrasts sharply with the 43% decline widely referred to by policymakers.

2.3 How Russian oil is priced

Global oil prices such as the Brent price of crude oil are only reference prices as opposed to transaction prices. The actual price paid for crude oil also depends on the type of crude oil and, most importantly, on the location where the oil is to be delivered. The price paid by the buyer differs from the price received by the oil producer, with the difference reflecting the costs of insurance and transportation in a competitive market. Russian oil export revenues depend on the fob price of Russian crude exports. The costs of shipping Russian oil to its final destination abroad are borne by the importer. The cif price paid by the importer exceeds the fob price by the costs of insuring the cargo and the freight costs of transporting the oil from the Russian export port to the importing sea port.

Abstracting from differences in the quality of the crude oil that may make crude oil more or less desirable from the point of view of a refiner, importers choose among alternative sources of crude oil based on the cif price at the import destination. Consider the example of a refinery in India that buys crude oil in global markets. If Russia wants to compete with other suppliers, it has to lower its fob price of oil to compensate the buyer for the additional insurance and transportation costs involved in delivering Russian oil from the Black Sea to India, for example, as opposed to crude oil from, say, the Persian Gulf. This means that having to redirect Russian crude oil exports from Europe to Asia raises the cost of transporting Russian crude oil and hence lowers the fob price that Russia can charge. Likewise, any insurance premia involved in moving Russian oil cargoes will lower the Russian fob price, increasing the wedge between the fob and cif price.

2.4 The evolution of the shadow fleet

Russia would not have been able to sustain its oil exports in 2023 and 2024 without access to a variety of means of shipping. The oil tanker fleet transporting Russian oil in 2023 consisted of oil tankers using Western maritime services subject to the price cap, tankers using these services fraudulently in violation of the price cap, and tankers not using Western maritime services at all. To the extent that the latter vessels were owned and insured in countries not implementing the price cap policy, they were not subject to sanctions. The Russian fob price is a weighted average of the prices of these shipments (including the fraudulent ones).

Tankers transporting oil valued above the price cap are often referred to as "shadow" tankers. The role of this shadow fleet increased, once the price cap became binding in the second half of 2023. The size of the shadow fleet is endogenous. Tankers are sold into the shadow fleet to arbitrage differentials in ship value that arise from sanctions, thereby dampening the effects of the sanctions themselves (similar to dynamics described in Brancaccio et al. (2020) and Kellogg and Sweeney (2023)). As discussed in Levi et al. (2023), as of mid-2023, shadow tankers accounted for 37% of total Russian oil exports. There is little evidence, however, that these shadow tankers constituted a fleet coordinated by Moscow. The Russian state-owned shipping company Sovcomflot controls only 30% of the tankers helping Russia to circumvent sanctions. Most of the remaining 70% was operated by tanker owners in other countries.

More than half of the seaborne shipments of Russian crude oil in mid-2023 relied on Western insurance. The continued reliance of many tankers in the shadow fleet (including some Russian ownwed tankers) on at least some Western maritime services has made them vulnerable to tightened U.S. sanctions (see Kennedy (2023)). Throughout 2023, the enforcement of the price cap was sporadic at best. In late 2023, efforts were made to tighten the enforcement, but with limited success. Only in January 2025, the United States sharply expanded enforcement by sanctioning over 180 vessels and associated entities involved in transporting Russian oil at prices above the G7 price cap.

3 Assessing the Effects of the Price Cap

The price cap was conceived by the U.S. Department of the Treasury as a response to widespread concerns that sanctions on Russia could inadvertently damage the global economy by dramatically reducing Russian oil flows and thereby increasing global oil prices. The price cap works by setting a cap of $60 per barrel on the fob price of Russian crude exported on tankers relying on Western insurance and related financial services after December 2022. Russian crude valued above this price cap can only be shipped on tankers not relying on Western maritime services. The intent was to make tankers unavailable to Russia, forcing Russia to lower its fob price and curtailing its crude export earnings while maintaining the overall supply in the global market. To the extent that Russia would evade the price cap by building a shadow fleet, the expectation was that this investment would constrain Russia's ability to finance the war.

The price cap had a multitude of potential effects. Some of these were related to political objectives, such as preserving the flow of oil in global markets by relaxing the EU ban on maritime services. Others were related to economic objectives, such as constraining the fob price of Russian oil exports and curtailing Russia's ability to finance its war effort. In addition, even the announcement of a possible price cap in June 2022 was thought, by some, to affect market expectations and hence the price of oil. In this section, we assess the empirical support for each of these effects, one at a time.

3.1 Financial costs to Russia

One of the most visible economic effects of the price cap has been to prompt Russia (and other players in this market) to assemble a shadow fleet of oil tankers not subject to the price cap. With the benefit of hindsight, creating a shadow fleet would have been unnecessary in early 2023, when the average fob price was below the price cap, because Russia could simply have relied on tankers using Western insurance. Presumably, Russia did not anticipate this outcome and instead expected to be forced to rely on a shadow fleet eventually. Under such expectations, it made sense for Russia to acquire as many oil tankers as possible before the demand for tankers surged and tankers became more difficult to find in the market at a reasonable price. Moreover, building a fleet takes time. Expanding the shadow fleet became even more important when the Urals fob price started exceeding the price cap in mid-2023. Thus, the case can be made that the price cap (or the expectation that the price cap would be binding) forced Russia to spend billions of dollars on assembling a shadow fleet.

However, there are countervailing arguments. As noted by Kennedy (2023), the core of the tanker fleet assembled by Moscow, starting in summer 2022, was made up of the roughly 80 tankers belonging to Russia's main state-owned shipping company, Sovcomflot. Sovcomflot was sanctioned by the EU shortly after the invasion of Ukraine, causing it to lose access to Western maritime services well before the price cap was implemented. These tankers becoming part of the shadow fleet thus cannot be attributed to the price cap.

In addition, the focus on the price cap ignores that Russia would have had to maintain a fleet of oil tankers even in the absence of the price cap, as commercial oil shipping in the Black Sea was curtailed by the expanding war with Ukraine. These tankers were needed to maintain the flow of Russian exports from the Black Sea to the Mediterranean Sea, where it could be transferred to other tankers or continue to its final destination. How important this motive was compared to that of circumventing the price cap is an open question.

Even more importantly, the Russian shipping company Sovcomflot only controls about 30% of the operating shadow tankers. The rest are operated by owners in many other countries, so much of the cost of assembling the shadow fleet was not borne by Russia. Finally, the increase in the role of shadow tankers has been mainly driven by more voyages from Russia, rather than an increase in the number of shadow tankers (see Levi et al. (2023)).

In short, to the extent that Russia invested in additional oil tankers in response to the price cap, this diverted resources from the war effort. However, this fact does not detract from our point below that the price cap contributed little to the decline in the Russian fob price, conditional on the Western maritime services ban having been relaxed. It is the latter effect that we turn to next.

3.2 Distinguishing political and economic effects

There was a set of potential sanction policies for governments to choose from, ranging from an EU oil embargo (A) and a ban on Western maritime services for transporting Russian oil (B) to a price cap on Russian oil exports to third parties (C). The EU's 6th sanctions package, which was passed on June 3, 2022, included both the oil embargo and the ban on European maritime services for transporting Russian oil (A+B), whereas what has become known as the G7 price cap maintained the embargo, while relaxing the ban on Western maritime services by allowing their use for shipments below a given price (A+C).

In assessing the effects of these policies, one must distinguish between their economic effects and the political constraints that caused them to be adopted. It is conceptually possible to separately consider the economic effects of the embargo, transportation services restrictions, and the price cap, or any combination thereof. Indeed, it is necessary to understand what may have happened in certain counterfactual scenarios that were not implemented, since this is what will allow us to make informed decisions about future sanctions regimes.

The important role of political constraints in 2022 is illustrated by the chronology of events. The EU's 6th sanctions package included both an oil embargo and a ban on European services for transporting Russian crude oil with these restrictions intended to take effect by the end of 2022. After this package was passed in June 2022, U.S. Treasury officials, some market participants and some foreign governments became concerned that the European maritime services to be banned by the EU (and other countries such as Norway and the U.K.) were necessary for Russian oil to reach the global market.[9] The fear was that the global oil price would spike and there would be a global recession if these Russian barrels were eliminated from the global supply.

[9] Regional price differentials are common when transportation infrastructure is capacity constrained. One such example is discussed in Kellogg and Sweeney (2023) who study the impact of the Jones Act on U.S. fuel prices. Another instance of this phenomenon was documented by Borenstein and Kellogg (2014) who studied the interplay of crude oil and gasoline markets during the shale oil revolution. Similarly, one would expect frictions in maritime transportation to produce a glut in Russia and scarcity in the rest of the world, but on a much larger scale.

One possible response would have been to reverse the ban on the use of European maritime services for Russian oil exports to third countries, but this option was considered politically infeasible, presumably because of the (incorrect) belief that Russia would be able to sell its oil to countries in Asia at the global price. Instead, the price cap was introduced, which linked access to European maritime services to the Russian fob price in an effort to gain political support from EU members.

In what follows, we demonstrate that the effects of the chosen sanctions policy (A+C) on the Russian fob price could have been achieved via an alternative policy that removes the price cap component (leaving only A). We show that an embargo that allowed Russia to use Western maritime services would have had essentially the same effect on the fob price as an embargo that was coupled with a price cap that allows Russia restricted access to Western maritime services. This result implies that the price cap had little to no effect on the fob price, despite being politically expedient.

To evaluate the economic relevance of the price cap for the Russian fob price, consider two scenarios that we observe in the data for 2023: one where the fob price is below the price cap and another where it is above. When the Russian fob price is below the price cap, the price cap is non-binding and Western maritime services can be used irrespective of whether the price cap is enforced or not. When the Russian fob price exceeds the cap, this is evidence that either there are sufficient transportation services not requiring Western maritime services to deliver all (or at least most) Russian seaborne exports to the customers, or the price cap is not being enforced. In either of these cases, a very similar economic outcome would have been observed if policymakers decided to abandon the price cap going forward from that point. Thus, the main role of the price cap was to facilitate a political agreement not to enforce the EU's ban on maritime services. This conclusion is not surprising because, as we will show, the conditions identified by Johnson et al. (2024) for a price cap to constrain the fob price were not met in 2023.

3.3 Empirical evidence on the Russian fob discount

Given that Russian oil export volumes have not declined, as noted in Section 2, any reduction in revenues must have reflected a decline in the fob price of Russian crude. Figure 4 examines how this price evolved and how price discounts relative to the global price of oil have affected Russian export earnings.[10] The fob prices of seaborne Russian crude are computed separately for Urals oil (Black and Baltic Sea) and ESPO

[10] Our analysis draws on fob price data from Platts and Argus for the ports of Primorsk (Baltic Sea), Novorossiysk (Black Sea) and Kozmino (Pacific Coast). There are no price data for the intermittent crude exports from Russia's Arctic ports. Prices may differ by port, reflecting differences in the quality of the oil exported as well as transportation costs. When price assessments for the same port and month differ across data providers, we average the prices.

oil (Pacific). The Urals fob price is a weighted average representing the average share of crude exported from the Baltic (41%) and Black Sea (16%) ports, respectively.[11]

There are two channels through which the price cap could have affected the Russian fob price. The most obvious would be a binding and well enforced price cap that yields Russian fob prices close to $60 per barrel. If Russian fob prices are below $60, the cap was set too high and is non-binding. If Russian fob prices are above $60, then the price cap ought to be binding but is either being circumvented fully or in part by the use of shadow tankers or is not being successfully enforced. Thus, the hypothesis that the price cap causes a reduction in the Russian fob price can be tested by evaluating the proximity of Russian fob prices to $60 per barrel. The fob price being substantially above the price cap at a minimum is evidence that the price cap has done little to reduce Russian oil revenues. The second potential channel through which the price cap could affect the Russian fob price is by altering expectations of market tightness in the global oil market in advance of the implementation of the price cap. We start by considering the first of these possibilities.

Figures 4(a) and 4(b) highlight several facts about the Russian fob price and, by extension, the effect of the price cap. For example, the Russian fob price has been systematically lower than the Brent price, which is the reference price for crude oil in Western Europe. Moreover, while the Russian Urals fob price has at times been below the $60 price cap and at times above it, the ESPO fob price has been consistently above the price cap. Finally, the Russian Urals fob price discount (relative to Brent) was between $20-$35 per barrel for most of 2022 and early 2023, but declined later in 2023. In contrast, the ESPO fob price discount has been stable with values near $5 to $15 since mid-2022. While we focus on Russian fob price data from data providers Argus and Platts, qualitatively similar results would have been obtained based on the Russian customs data in Hilgenstock et al. (2023) that end in March 2023.

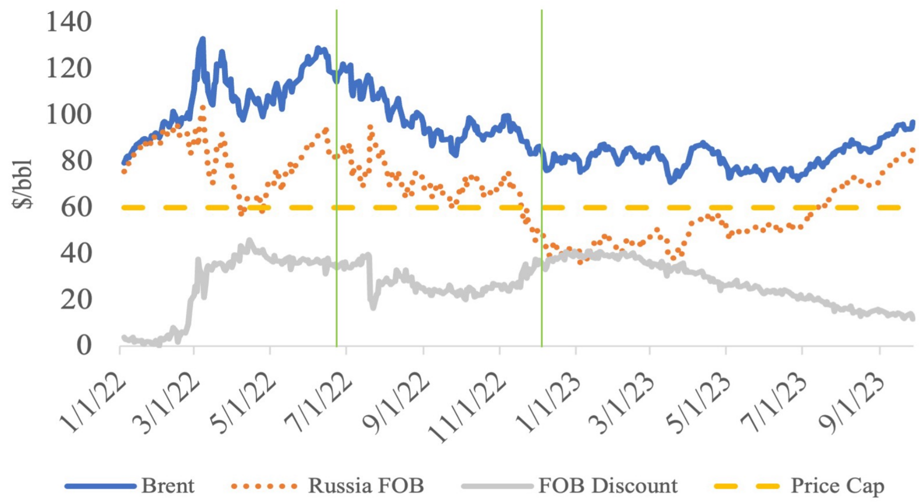
Figure 4 provides three insights. First, the fact that the price discount in early 2023 was not larger than during the height of voluntary import restrictions in 2022 suggests that the price cap had no incremental effect on the fob price, once the import restrictions were formalized as an oil embargo.

Second, the price cap does not help explain why the average Urals fob price dropped far below $60 in the first half of 2023. In the first half of 2023, importers of Russian oil had the same access to Western maritime services as they would have had if all restrictions on maritime services had been removed. It is in this sense that the price cap

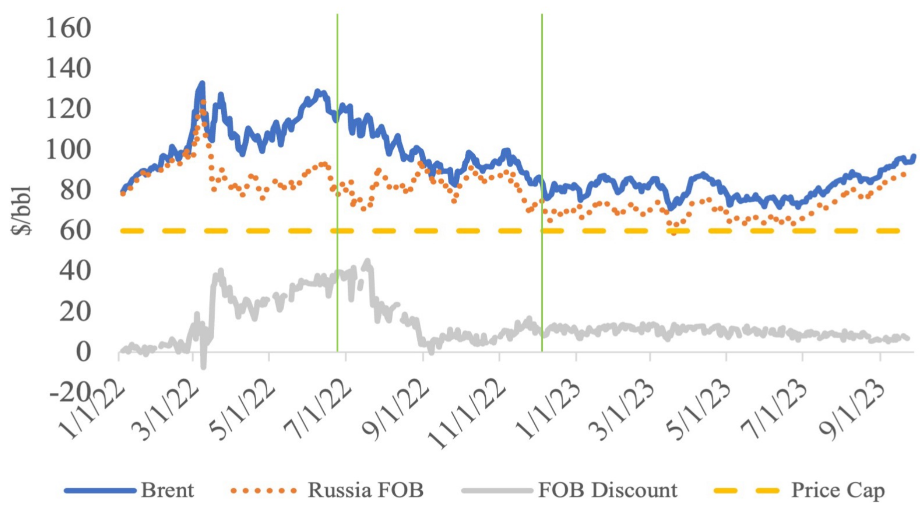
[11] In constructing the weights, we abstract from oil exports from Artic ports since these exports are comparatively small as a share of total Russian crude exports, take place only intermittently, and no fob price data for Arctic ports are being collected by Argus or Platts. It should also be noted that the share of Black Sea Russian crude exports is difficult to pin down since Kazakh oil that arrives in Russia by pipeline is also exported through the same port. Different data providers make different assumptions in that regard, but similar results are obtained under alternative assumptions.

Figure 4: Russian fob price discounts relative to Brent since January 2022

(a) Urals Crude



(b) ESPO Crude



Source: EIA, Argus, Platts, Clipper, Bloomberg, Kpler and authors' calculations. Green vertical lines are placed on June 28, 2022 (G7 leaders' communiqué) and December 5, 2022 (commencement of embargo and price cap) policy was effectively a policy of circumventing the EU services ban. If some Russian exports were actually constrained by the price cap, while others were not, one would have expected the average fob price to be above the price cap by construction.

Third, to the extent that the objective of the price cap was to deprive Russia of financial gains from high global oil prices, this policy clearly has not been successful, given that the average Russian fob price has substantially exceeded $60 since mid-2023. One may object that the average fob prices in Figure 4 for the second half of 2023 incorporate shadow fleet shipments and that the price of Russian oil shipped on tankers using Western insurance may have been lower than the average fob price. All this really says, however, is that the price cap has been of limited relevance for the fob price because Russia has been able to use oil tankers not relying on Western insurance or tankers operating in violation of the price cap.

These conclusions raise three questions. One question is whether the Argus and Platts measures of the Urals fob price are accurate? The fact that broadly similar estimates are implied by the Russian customs data analyzed in Hilgenstock et al. (2023) suggests that measurement error in the Russian fob price is not a primary concern.[12]

It is also important to understand how the Russians circumvented the price cap when the Russian fob price moved above the cap in the second half of 2023. One answer to the latter question is access to oil tankers that operate without Western services and are therefore not covered by the price cap. As of December 2023 this fleet comprised several hundred vessels. Bloomberg estimates that by September 2023 more than 70% of 2023 Russian seaborne cargoes were loaded onto ships that were not subject to the rules imposed under the price cap (see Nightingale et al. (2023)). Similarly, analysts at Argus estimate that much of the Russian seaborne exports relied on vessels not covered by Western insurance. The other answer is that the price cap was not rigorously enforced in 2023, allowing shipping companies to move Russian oil in violation of the price cap, while using Western maritime services. This point is important because the absence of a shadow fleet and strict enforcements are the key conditions required for a price cap policy to work (see Johnson et al. (2024)).

[12] Vakulenko (2023) calls into question the ability of data providers such as Argus to accurately measure the fob price of Urals oil. He suggests - without providing evidence - that seaborne Urals oil directly delivered to Russian owned refineries (notably in Italy and in the Netherlands) was sold at prices much closer to the Brent price and that these sales are not captured by the Argus fob price. Such sales, according to Vakulenko (2023) ceased after November 2022 with the imposition of the oil embargo, so his argument, even if correct, would not apply to the 2023 data. Vakulenko does not explain why these sales would not be covered by the Russian customs data, except to hint at the possibility that the fob price of these deliveries may indeed be far below Brent, as indicated by Argus data and the Russian customs data, and that the resulting excess profits of Russian-owned refineries selling refined products in Europe at prevailing market prices might have been repatriated. This more plausible interpretation, however, directly contradicts his premise that Argus mismeasures the fob price because without access to cheap oil there are no excess profits.

Finally, if the price cap was not enforced, why was the Russian fob price so far below the global price in early 2023? In Sections 4 and 5 we examine two alternative explanations of this result based on the fob price data documented earlier. Our analysis focuses on a comparison of January 2022, before any possible mismeasurement issues with the Russian fob price arise, and March 2023, when the oil embargo and price cap had taken full effect. We show that the decline in the fob price relative to Brent can be explained even in the absence of an effective price cap. We defer until Section 6 an analysis of the argument that the effects of the price already materialized well before March 2023 because the market expected the price cap to be successful. We defer to the conclusion a discussion of how the Urals price discount has evolved since March 2023.

4 The Effect of Higher Insurance & Transportation Costs

We now turn our attention to shipping insurance and transportation costs. Prior to 2022, Europe was the primary destination for Russian crude. After the EU and other countries curtailed their oil imports from Russia, Russia was forced to sell its crude to more distant buyers, an effect that can be thought of as "market segmentation". Shipments to more distant destinations raised both the cost of insurance and the cost of transportation. As the distance over which the Russian oil has to be transported increases, transportation costs rise, even controlling for tanker and insurance rates. Not only variable costs of shipping such as crew costs, fuel costs, and insurance costs depend on distance, but tankers are spending more time at sea, reducing the effective size of the tanker fleet and raising tanker rates. Moreover, the need to partially replace Russian pipeline exports of crude to Europe by seaborne exports to Asia added to the scarcity of tankers. This is expected to raise tanker rates even if there is no change in insurance rates.[13] Thus, to remain competitive, Russia was forced to offer a larger price discount compared to the Brent price of oil. A more formal analysis of this point is provided in Section 5.

A natural approach to evaluating the increase in transportation costs caused by having to ship Russian crude oil over longer distances is to compare the fob discount for Russian crude in January 2022, before the invasion, to the discount in March 2023. This task is complicated by the fact that standard Russian fob price series for Urals crude oil were discontinued, as trading on traditional routes from the Baltic and from the Black Sea ceased in 2022. In contrast, the Argus fob price series for trade with

[13]For a discussion of changes in insurance premia the reader is referred to Appendix A.

India emerged only in early 2023 and is not available farther back in time. As to the oil trade between Russia and China, the data are even more fragmentary.

Table 1: Discount on Russian fob price as of January 2022 (U.S. Dollars per Barrel)

Russian fob export price	Price discount relative to		
	Argus Urals cif Rotterdam	Argus North Sea Dated	Brent Spot
Argus Urals Primorsk (Baltic Sea)	1.29	2.39	1.80
Argus Urals Novorssiysk (Black Sea)	0.87	1.97	1.38
Argus ESPO Kozmino (Pacific)	-	2.11	1.52
Platts Urals Primorsk (Baltic Sea)	2.45	3.55	2.96
Platts Urals Novorssiysk (Black Sea)	2.58	3.68	3.09
Averages Urals Primorsk (Baltic Sea)	1.87	2.97	2.38
Average Urals Novorssiysk (Black Sea)	1.72	2.82	2.23

Notes: The cost of insurance and freight adds almost $2 to the price, taking the Rotterdam cif price for Urals oil as the benchmark, which controls for the quality of the oil. North Sea Dated is a benchmark for a different type of crude. The additional quality difference is reflected in a larger discount of near $3. North Sea Dated is more representative for the price of oil in the Atlantic Basin than Brent, which is included as one among several benchmarks in North Sea Dated.

Nevertheless, we can glean some information from the price data. Table 1 reports the difference between the fob price for Russian Urals crude and the cif price for Urals crude in Rotterdam, one of the major destinations for Russian crude in Western Europe, in January 2022, before the invasion. Focusing on Urals crude helps control for differences in the quality of the oil. The cost of insurance and freight adds almost $2 per barrel to the price, implying a discount of $2 on the fob price.[14] Using North Sea Dated instead (a recently introduced new benchmark that is more accurate than Brent), the discount is near $3, which reflects the fact that the quality of North Sea Dated oil differs from that of Urals oil.

Table 2 focuses on data for March 2023, about one year after the invasion of Ukraine, when trade patterns had changed and the Rotterdam price series had been discontinued. It shows a discount of $17 for Russian shipments of Urals crude from the Baltic Sea or the Black Sea to India, which had replaced Rotterdam as one of the primary destinations. Given that increases in the insurance rate are negligible, as discussed in Appendix A, this evidence suggests that of the $34 -$2 = $32 increase in the discount relative to Brent for oil exported from Black Sea and Baltic Sea ports about $15 re-

[14] After January 2022, there is a growing gap between Brent/North Sea Dated and Rotterdam cif that is not related to the quality of the oil, but apparently customers' unwillingness to buy this oil at any price. Of course, the interpretation of cif Rotterdam also becomes murky, when there is (almost) no trade. The Rotterdam series stops in December 2022.

Table 2: Discount on Russian fob price as of March 2023 (U.S. Dollars per Barrel)

Russian fob export price	Price discount relative to		
	Argus Urals cif India	Argus North Sea Dated	Brent Spot
Argus Urals Primorsk (Baltic Sea)	17.19	33.83	33.97
Argus Urals Novorssiysk (Black Sea)	17.65	34.30	34.43
Argus ESPO Kozmino (Pacific)	-	10.76	10.90

Notes: The fob price discount has grown by $15, taking the Indian cif price as the benchmark. The latter price is available only starting in March 2023. Similar Urals cif prices for China are not available, as China is mainly importing ESPO oil from Asian ports.

flected the increase in transportation costs associated with redirecting oil exports from Europe to Asia. This estimate is reasonable, given reports in Hellenic Shipping News (2022) on December 16, that freight rates for shipping Urals oil to India had risen from less than $3 before February 2022 to between $11 and $19, implying a rise in the fob discount of between $8 and $16. Accounting for insurance costs would further raise this estimate by several dollars. Our estimate of $15 is well within the implied range. This leaves a residual of $17 to be explained relative to the Brent price.[15]

One possible explanation of this residual raised in Cook et al. (2023) is that Russian oil companies may control the shipping of Urals oil to India (as well as most trading companies arranging for sales of Russian oil) and use their market power to overcharge Indian customers for transportation services. By declaring the price of their exports at the port to be $60 per barrel or less, these companies retain access to Western insurance, but the price paid by Indian importers is substantially higher reflecting excessive charges for transportation. These excess charges are retained by the Russian oil companies and may or may not be available to finance the war. In other words, Russian exports nominally satisfy the price cap, as indicated by the Urals fob price, yet the price cap is circumvented. This in turn means that the residual is simply explained by fraud. In this interpretation, only the oil embargo matters through its effect on transportation costs.

It is important to understand that this explanation is a conjecture rather than an established fact. How close the links of trading companies are to Russian oil companies or the extent to which these companies control the vessels involved in this trade remains an open question. Moreover, is it not clear why Russian oil companies would choose to declare the price of their Urals exports to be far below the price cap rather

[15] Cook et al. (2023) quote Argus as reporting a transportation cost of $9 (excluding insurance costs) for the route from the Baltics to India, but that estimate appears to relate to May through July 2023, when transportation costs had declined relative to March 2023.

than barely below the price cap. Nor is it clear why Russia would care about access to Western insurance to the extent that India recognizes Russian insurance. Indeed, many vessels used in shipping Urals oil are operated by Russia using Russian insurance. For obvious reasons, it is difficult to assess the veracity of this conjecture, since all parties involved would have an incentive not to reveal their activities.

An alternative explanation of the $17 residual is the market power of India in the Urals market as the only remaining large buyer of this oil. This explanation is explored in Section 5 with the help of a calibrated model of the global oil market. One advantage of this explanation compared to earlier explanations is that it helps understand why the fob price of Urals oil fell well below the price cap of $60 per barrel in early 2023. Another advantage is that our explanation may be supported empirically by evaluating India's cif prices for Urals imports from Russia and other oil imports, as discussed at the end of Section 5.

In contrast, the fob discount for Russian oil exported from Kozmino on the Pacific coast is $11 per barrel. In the year preceding the invasion of Ukraine, the spread of Kozmino ESPO fob prices over the North Sea Dated price averaged $1.44 per barrel, suggesting a drop in the ESPO fob price by $12 since the invasion. To the extent that much of the oil from Pacific ports is shipped to China, the result that the overall effect on the price discount is smaller than for India is not surprising since the shipping distances are not much greater than those to Japan or South Korea and insurance rates have not materially changed. While we do not have the necessary data to decompose the $12 increase in the ESPO discount further, it would be surprising if the transportation cost increased by more than a few dollars, so much of the increase in this discount is likely to reflect the growing market power of China in the ESPO market. We rely on the model in Section 5 to quantify these effects.[16]

Our analysis so far suggests the following conclusions about the economic determinants of Russian price discounts. First, lower global oil prices starting in late 2022 took much of the bite out of the oil price cap, allowing Western companies to participate in the Russian oil trade more easily in the first half of 2023. Second, our estimate of the added transportation cost of $15 per barrel for shipping Urals oil to India rather than Western Europe is substantial, as is the residual of $17 estimate left unexplained by higher transportation cost. Much of this higher transportation cost reflects the increase in shipping distance caused by the oil embargo. The importance of higher insurance rates is likely to be negligible, as alternative low-cost insurance providers have filled the void left by Western insurance companies and Russian oil increasingly

[16]The increase in the discount relative to Brent and North Sea Dated is also consistent with the fact that some of the oil shipped from Kozmino was destined for countries such as India that traditionally did not import oil from Kozmino and that now ship oil over longer distances. Those shipments, however, account for only a small fraction of Russian oil exports from Kozmino.

is shipped on tankers whose ownership cannot be traced easily, making enforcement difficult.

Third, our $12 estimate of the increase in the ESPO discount, while smaller, is still substantial. The latter estimate obviously has to be taken with a grain of salt, given that the price data for China's ESPO imports are likely less reliable. Higher transportation costs are unlikely to be the primary driver of this increase.[17] In Section 5, we re-examine the economic determinants of the Russian fob discount more formally through the lens of a calibrated model of the global oil market.

5 Model and Results

The goal is to describe how the latent effects of unobservable market power may be recovered from observable prices and quantities for January 2022 and March 2023. March 2023 is a natural point of comparison as the sanctions on Russian crude and product exports imposed in December 2022 had taken full effect by March. We seek to quantify three effects in sequence. First, a "supply and demand effect" that reflects changing business cycle conditions in the global market for crude oil as well as exogenous changes in the supply of oil from other producers. Second, given the segmentation of the crude oil market after the invasion of Ukraine and the rerouting of Russian crude exports, we allow a "transportation cost effect" to increase the cost of insurance and freight due to more crude oil being shipped by tankers rather than by pipeline, longer shipping routes, and the Black Sea port Novorossiysk being close to a war zone. Third, the "market power effect" allows India and China to exercise partial monopsonistic market power in their respective segmented markets for Russian crude oil. This is plausible not only because, together, they purchased the vast majority of Russia's crude oil in the post-sanctions period, but because their oil import activities are dominated by large state-owned firms (Indian Oil Corporation in India, China National Petroleum Corporation, and Sinopec).

To this end, we calibrate our model to market data for January 2022 and March 2023, which allows us to recover several unobservables. These include the counterfactual prices and quantities with and without the three effects in question, and a measure of the market power of the major buyers in the Urals and ESPO markets in March 2023. The main assumptions of the model are (1) a competitive and globally integrated market for crude oil before the sanctions; (2) (piece-wise) linear demand and supply functions; and, (3) a segmented market for crude oil after the curtailment

[17] For example, China also imports Russian crude from Artic, Baltic and Black Sea ports. There is every reason to believe that the latter trade is subject to an even larger transportation cost premium than Russian oil trade with India, because the distances are substantially greater. However, there are no data for these routes that would allow us to quantify these costs.

of Western demand for Russian crude oil. In particular, we assume that Urals crude is mainly traded with India and ESPO crude is mainly traded with China, allowing both countries some degree of monopsony bargaining power with Russia. Their residual demand is aggregated with the rest-of-the-world demand and met by the supply of non-Russian crude oil in a competitive market. The key feature of the model is that under the oil embargo no other country competes with India (China) for Russian Urals (ESPO) oil, but the world market oil suppliers compete with Russia for India's (China's) demand.

The model deliberately does not incorporate the price cap. As we demonstrated in Section 3, as of March 2023, the price cap had no meaningful effect on Russian crude oil quantities and prices as the Urals fob price was well below \$60. Nor was there a meaningful effect on ESPO exports, as the latter fob price was well above \$60. Dodonov et al. (2023) estimates that only 12% of Russian ESPO crude from Kozmino was shipped with Western insurance even in June 2023, which suggests that the effect of the price cap in March 2023 may be ignored for our purposes.

We do not model explicitly marginal costs, oil production technologies, the storage technology within Russia, and the transport technology within Russia. The reason for excluding storage is that Russia lacks storage capacity and hence must export the oil it produces. Russia's ability to divert oil exports from India to China is limited by transportation costs and pipeline bottlenecks, so Russia confronts only one large buyer in each of its segmented markets. Since the model is static, after sanctions are imposed, India and China, respectively, do not decide their oil imports from Russia and from the rest of the world sequentially, but simultaneously. Equilibrium conditions for all three markets must be satisfied at the same time. When the buyer withholds demand from Russia in order to lower Russia's fob price, it must satisfy more residual demand at world market prices. Our model does not assume that the buyer solves this tradeoff problem optimally. Rather, the purpose of the model is to use the market data to back out how much market power the buyer actually has.

The Russian supply side is modeled by supply functions. Russia's supply before sanctions can be understood as the aggregate supply of Urals and ESPO. No assumption is made on whether marginal costs of Urals and ESPO are the same in these markets before sanctions. After sanctions, these markets are considered in a disaggregated manner in order to allow for (but not assume) monopsony power. If market data were consistent with a competitive market after sanctions, our model would automatically aggregate Russia's supply of Urals and ESPO.

We use short-run demand and supply elasticities to describe the competitive equilibria, while the post-embargo market allows for market power. These elasticities are only assumed to hold in the counterfactual competitive market equilibrium, not in the model with market power. They allow us to pin down demand and supply functions that are then disaggregated and used for the market with market power. Our assumption of a highly inleastic Russian oil supply function is consistent wih Russia's inability to stimulate oil production, given the lack of imported equipment and expertise, as well as its apparent unwillingness to reduce its oil production driven by the need to generate foreign exchange income.

5.1 The "before sanctions" model

Let p be the fob market price per barrel of crude oil. For simplicity, we assume that the aggregate supply function is linear and takes the form $s(p) := c + kp$ with $c, k > 0$. The supply of crude oil by Russia (R) is a fraction $\rho \in (0, 1)$ of aggregate supply such that $s_R(p) := \rho s(p)$. Let $t \geq 0$ denote the cost of insurance and freight per barrel of crude oil, so $p + t$ represents the cif price. We assume that global demand is piece-wise linear,

$$d(p + t) := \min\{\ell - m(p + t), b\} \text{ with } \ell, b, m > 0. \tag{1}$$

The kink and vertical "leg" reflects the global refinement capacity b. The demand by China (C) and India (I) is $d_C(p) := \gamma_C d(p)$ and $d_I(p) := \gamma_I d(p)$, where $\gamma_C, \gamma_I \in (0, 1)$ are fractions of global demand with $\gamma_C + \gamma_I < 1$. The combined demand by all net oil importers other than China and India (O) is denoted by $d_O(p) := (1 - \gamma_I - \gamma_C)d(p)$.

We assume that prior to the invasion of Ukraine, market participants were price takers in the short run. Although Russia, China, and India are non-negligible in the sense that their absence could affect prices, oil-consuming countries compete in a Bertrand fashion for crude oil. This assumption is justified as long as global supply does not reach global refinement capacity.[18] The equilibrium fob price p^* is determined competitively by $s(p^*) = d(p^* + t)$. Global demand at the equilibrium price must equal global supply.

5.2 Calibration of the "before sanctions" model

The model is calibrated as shown in Table 3. The slopes of the short-run oil demand and oil supply curves are approximated based on estimates of short-run price elasticities in the oil market. These price elasticities of demand for and supply of crude

[18] If any country with positive net demand were to credibly withhold part of their demand, other countries *together* would be able to absorb the freed-up supply without exceeding the refining and storage capacity in the rest of the world. Similarly, if Russia or any other supplier individually withholds supply, other suppliers and storage can make up the shortfall. Under these assumptions, a competitive market is a reasonable approximation of reality in the short run.

Table 3: Model Input and Data

Variable	Unit	Model Input	Data
Price elasticity of aggregate demand $e_D(p^* + t)$		-0.20	Kilian (2022) -0.20
Price elasticity of aggregate supply $e_S(p^*)$		0.05	Kilian (2022) 0.05
January 2022			
Market FOB price p^*	US$/b	86.74	Argus North Sea Dated 87.10
			Argus Urals FOB Primorsk 84.71
			Argus Urals FOB Novorossiysk 85.13
			Argus ESPO Blend FOB Kozmino 84.99
CIF-FOB markup t	US$/b	1.23	Argus CIF Rotterdam Urals 86.00
Russia's quantity $s_R(p^*)$	b/d	4,296,445	4,296,445
Other producers' quantity $s_P(p^*)$	b/d	22,592,069	22,592,069
Total quantity q^*	b/d	26,888,514	26,888,514
India's quantity $d_I(p^* + t)$	b/d	3,558,958	3,558,958
China's quantity $d_C(p^* + t)$	b/d	6,598,794	6,598,794
Other buyers' quantity $d_O(p^* + t)$	b/d	16,730,762	16,730,762
March 2023			
World market FOB price p_W^*	US$/b	78.29	Argus North Sea Dated 78.29
Urals FOB price p_U^* (quantity-weighted mean of Argus)	US$/b	44.35	Argus Urals FOB Primorsk 44.46
			Argus Urals FOB Novorossiysk 44.00
ESPO FOB price p_E^*	US$/b	67.53	Argus ESPO Blend FOB Kozmino 67.53
CIF-FOB World market markup t_W	US$/b	2.54	BDTI Increase Jan 2022/March 2023 2.07
CIF-FOB Urals markup t_U	US$/b	17.46	CIF-FOB Urals Primorsk - India 17.35
			CIF-FOB Urals Novorossyk - India 17.81
CIF-FOB ESPO markup t_E	US$/b	5.00	
Other producers' quantity $s_P(p_W^*) = q_W^*$	b/d	26,479,186	26,479,186
Other buyers' quantity in the world market $d_O(p_W^* + t_W)$	b/d	17,247,474	17,247,474
India's quantity from Russia $d_I(p_U^* + t_U) = q_U^*$	b/d	2,097,165	2,097,165
China's quantity from Russia $d_C(p_E^* + t_E) = q_E^*$	b/d	1,925,150	1,925,150
Other buyer's quantity from Russia	b/d	0	1,061,671
Russia's quantity	b/d	4,022,315	5,083,986
India's quantity in the world market $d_I(p_W^* + t_W) - q_U^*$	b/d	2,381,596	2,381,596
China's quantity in the world market $d_C(p_W^* + t_W) - q_E^*$	b/d	6,850,116	6,850,116

oil are based on a recent survey of oil demand and supply elasticities in Kilian (2022). The market price p^* is set equal to the quantity-weighted mean of Argus fob prices. Russian oil exports account for 4,296,445 b/d of the $q^* = 26,888,514$ b/d total of worldwide oil exports in January 2022 (or 15%).[19] Finally, we assume that exports via the Druzhba pipeline are sold at the Urals Primorsk fob price and exports on the ESPO Daqing pipeline are sold at the ESPO Blend Kozmino fob price. About 67% of Russian exports are seaborne, 18% go through the Druzhba pipeline, and 15% through the ESPO Daqing pipeline. This yields a quantity-weighted mean fob price of $p^* = 86.74$ $ per barrel.

We calibrate the model as follows: Since $e_D(p^*) = \frac{\frac{\Delta q}{q^*}}{\frac{\Delta p}{p^*+t}}$, the slope of the aggregate demand function is $-m = e_D(p^*)\frac{q^*}{p^*+t}$. The intercept of the aggregate demand function is then $\ell = q^* + m(p^* + t)$, where the observed prices and quantities are assumed to equal the equilibrium prices and quantities. Similarly, we derive the slope and intercept of the aggregate supply function from the price elasticity of supply in equilibrium and the equilibrium price and quantity. Finally, the fraction Russia's supply relative to total supply and the fractions of India's and China's demand relative to aggregate demand are derived by straightforward calculations. This parameterization corresponds to the second column in Table 4.

5.3 The "after sanctions" model

The sanctions have two main components: First, a coalition of net oil importers curtailed its demand for Russian crude oil. This created a segmented market for crude oil with only India and China buying large quantities from Russia and other net oil importers purchasing crude from other suppliers. Second, a price cap of $60 per barrel was imposed on all shipments of Russian crude oil insured by Western insurance. Given the evidence presented in Section 3 that the price cap is either non-binding or binding but unenforced throughout, we exclude it from our calibrations, although it can be shown that our results would be robust to allowing for an empirically plausible fraction of exports being subject to the price cap.

We assume that the market is segmented into three markets: one possibly imperfectly competitive market for Russian Urals and India, one possibly imperfectly competitive market for Russian ESPO Blend and China, and one competitive market for the residual demands of both China and Russia, the demand by the rest-of-the-world, as well as the supply by producers other than Russia. This segmentation,

[19] All data for seaborne exports come from tankertracker.com. Data on the ESPO Daqing pipelines come from the OPEC Monthly reports. Data on the Druzhba pipelines are from Eurostat as reported by Bruegel. The latter have been converted from metric tonnes into barrels using a factor of 7.3122. We assume 31 days per month for the month of January.

which reflects geographic proximity and actual crude oil trade flows, helps explain why neither India nor China necessarily have full monopsony power in the markets for Urals and ESPO, respectively. India imports mainly Russian Urals crude from the Baltic Sea and Black Sea ports, whereas China imports mainly the ESPO Blend from Pacific ports.[20]

Because of the market segmentation, there are now three prices in the model. We denote the per barrel fob prices for Urals, ESPO, and rest-of-the-world by p_U, p_E, and p_W, respectively. Supply and demand functions are defined as before (with intercepts and slopes now calibrated to the March 2023 data in Table 3) except that Russia's supply is now split into the supply of Urals and the supply of ESPO crude, respectively. We define $s_U(p) := \rho_U s(p)$ and $s_E(p) := \rho_E s(p)$ as Russia's supply functions for Urals and ESPO, respectively, with $\rho_U, \rho_E \in (0,1)$ and $\rho_U + \rho_E < 1$. The combined supply by producers (P) other than Russia is $s_P(p) := (1 - \rho_U - \rho_I)s(p)$.

The cost of insurance and freight in the markets for Urals and ESPO crude exports and in the (rest-of-the) world market are denoted by t_U, t_E, and t_W, respectively. Equilibrium fob prices (p_U^*, p_E^*, p_W^*) for all three markets are given by

$$\alpha_I s_U(d_I^{-1}(s_U(p_U^*)) - t_U) = s_U(p_U^*), \tag{2}$$

$$\alpha_C s_E(d_C^{-1}(s_E(p_E^*)) - t_E) = s_E(p_E^*), \tag{3}$$

$$s_P(p_W^*) = d_O(p_W^* + t_W) + d_I(p_W^* + t_W) - q_U^* + d_C(p_W^* + t_W) - q_E^* \tag{4}$$

where $q_U^* = s_U(p_U^*)$ and $q_E^* = s_E(p_E^*)$. The α factors in equations (2) and (3) represent the degree of monopsony bargaining power of India and China in the markets for Urals and ESPO, respectively. Recall that in a monopsonistic market, the monopsonist would maximize consumer surplus by considering the point where the marginal cost of purchasing equals marginal gross consumer surplus. In a linear setting, the curve representing the marginal cost of purchasing is twice as steep as the supply curve. Thus, with full monopsony power we have $\alpha = \frac{1}{2}$. On the other hand, in competitive equilibrium without any monopsony power, we have $\alpha = 1$. In other words, the smaller α, the larger is the monopsony power of the buyer.

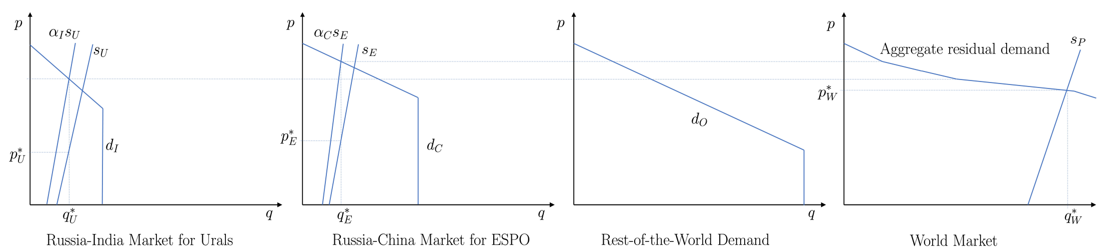
To understand the composition of the inverse demand functions and the supply functions in equations (2) and (3), recall that the monopsonist withholds demand compared to the competitive equilibrium. Thus, the monopsonist has strict positive excess demand at the monopsonistic price. The effective price for the satisfied monopsonistic demand can be computed by plugging in the supply at the monosponistic price

[20] This pattern seems to be driven by the vast distance between the Baltic Sea and China. Even though there exists a connection between the Druzhba and ESPO pipeline system, pipeline capacity constraints have forced Russia to exports its Urals crude by sea.

into the inverse demand function. That is, $d_I^{-1}(s_U(p_U^*))$ is the effective price that determines India's demand in the market for Urals. Thus, if the α's were equal to $\frac{1}{2}$, equations (2) and (3) are just an alternative way of writing marginal purchase cost equals to marginal gross consumer surplus. If the α factors are equal to 1, then the effective price is the cif price. The cif price minus the cost of insurance and freight is the fob price. This explains why the transport costs appear on the l.h.s. of equations (2) and (3). See Appendix B for a detailed derivation of equations (2) and (3).

Note that the r.h.s. in equilibrium condition (4) represents the combined *residual* demand obtained by aggregating the *residual* demand of China and India with the demand from the rest of the world. Our assumption is that India and China go to the world market to satisfy their residual oil demand not satisfied by Russia.[21]

Figure 5: Illustration of a Segmented Market Equilibrium (p_U^*, p_E^*, p_W^*)



The segmented market equilibrium is illustrated schematically in Figure 5. For this illustration, we set cost of insurance and transportation to zero in all markets in order to not complicate the graphs any further. The left-most chart illustrates the outcome with market power α_I in the Russian-Indian market for Urals. Note that after satisfying demand q_U^*, India has a residual demand function depicted to the right of q_U^* in the left-most chart. Similarly, the second chart illustrates the outcome with market power α_C in the Russian-Chinese market for ESPO. Again, after satisfying demand q_E^*, China has a residual demand function depicted to the right of q_E^*. The third chart depicts the demand function of buyers other than India and China. The right-most chart aggregates the residual demand functions from the first two charts and the demand function of the third chart into an aggregate residual demand function. It also depicts the supply by producers other than Russia and the resulting competitive market equilibrium p_W^* in that market.

Table 4: Calibration Results

	January 2022	March 2023
Increased Transportation Costs	No	Yes
Market Power	No	Yes
p^*	86.74	78.72
q^*	26,888,514	30,569,355
k	30,999	19,416
c	24,199,663	29,040,888
m	67,244	76,469
ℓ	32,803,987	36,683,227
ρ_U	n.a.	0.07
ρ_E	n.a.	0.06
ρ	0.16	0.13
γ_I	0.13	0.15
γ_C	0.25	0.29
α_I	n.a.	0.87
α_C	n.a.	0.83

5.4 Calibration of the "after sanctions" model

This model cannot be calibrated directly because the price elasticities discussed earlier relate to a competitive equilibrium in the global market. The price elasticities associated with outcomes in the segmented markets may differ. Hence, we cannot use standard price elasticity estimates to calibrate the slopes and intercepts of the demand and supply functions in the segmented markets.

To wit, we construct a counterfactual aggregated market that would have emerged without sanctions. We then assume that the price elasticities hold in the competitive equilibrium of that counterfactual aggregated market. This allows us to compute the slopes and intercepts of global demand and supply, given the competitive equilibrium of the counterfactual aggregated market. We know that if we were to disaggregate demand and supply of that counterfactual market into segmented markets, then it should fit our data on the segmented markets allowing for some degree of monopsony power on part of India and China. These arguments yield a system of equations whose solution determines the competitive equilibrium in the counterfactual aggregate market along with the market share of Russian Urals and ESPO as well as India's and China's market shares. This competitive aggregate model without sanctions serves as a useful benchmark. Importantly, it helps determine the degree of monopsony bargaining power of India and China in the segmented markets, as measured by their respective α. Appendix B describes this calibration in more detail.

[21] This assumption would be violated, for example, if their demand in the world market were largely determined by long-term purchasing contracts for crude oil, in which case there would be limited room for them to act in the spot market.

Table 5: Crude Oil Prices and Russian Crude Oil Quantities Before and After Sanctions

	January 2022		March 2023		**Overall change**	
Increased Transport Costs	No		Yes			
Market Power	No		Yes			
Crude Oil Prices	US$/b		US$/b		US$/b	% change
Model						
Market FOB price p_W^*	86.74		78.29		-8.45	-9.74%
Urals FOB price p_U^*	86.74		44.35		-42.39	-48.87%
ESPO FOB price p_E^*	86.74		67.53		-19.21	-22.15%
Actual data						
Argus North Sea Dated	87.10		78.29		-9.42	-10.81%
Argus Urals FOB Primorsk	84.71		44.46		-40.25	-47.52%
Argus Urals FOB Novorossiysk	85.13		44.00		-41.13	-48.31%
Argus ESPO Blend FOB Kozmino	84.99		67.53		-17.46	-20.54%
Russian Crude Oil Quantities	b/d	% share	b/d	% share	b/d	% change
Model						
Russian export	4,296,445		4,022,315		-213,542	-4.97%
Indian import from Russia	0	0.00%	2,097,165	52.14%	2,097,165	n.a.
Chinese import from Russia	1,215,255	28.29%	1,925,150	47.86%	709,895	58.42%
Others import from Russia	3,081,190	71.71%	0	0.00%	-3,081,190	-100.00%
Actual data						
Russian export	4,296,445		5,083,986		787,541	18.33%
Indian import from Russia	0	0.00%	2,097,165	41.13%	2,097,165	n.a.
Chinese import from Russia	1,173,765	27.32%	1,925,150	37.87%	751,385	64.01%
Others import from Russia	3,122,680	72.68%	1,061,671	20.88%	-2,061,009	-66.00%

Notes: For the March 2023 model, we omitted quantities of Russian crude oil imported by countries other than India and China so as to match our stylized segmented markets model assumption. This explains the differences between the model export data and the actual data in March 2023.

5.5 Discussion of model results

Table 4 presents the parameters of the models calibrated using January 2022 and March 2023 data. The latter model allows for sanctions-related mechanisms, such as increases in the cost of shipping Russian crude oil to its destination and in the market power of India and China, reflecting the segmentation of the oil market. Table 5 compares selected oil prices, the volume of Russian crude oil exports by destination, and other important quantities before and after the sanctions.[22] Our calibrated models closely match the changes in prices and quantities in the actual data, with Russian Urals crude receiving $44/bbl in March 2023, as compared to the benchmark global price of $78/bbl. The world market price of crude oil declines by 10% in the model, close to the 11% decline observed in the actual data.

Having demonstrated that our model can approximately reproduce the market conditions before and after the sanctions, in Table 6 we quantify each of the three economic mechanisms underlying this change: (1) shifts in supply and demand that are unrelated to the sanctions, (2) the embargo-induced increase in transportation costs, and (3) the increase in Chinese and Indian market power caused by the embargo.

The global benchmark oil price in March 2023 was $8.45 lower than in January 2022, an effect the model attributes primarily to shifts in global supply and demand that are unrelated to the sanctions and that did not materially change the direction of Russian crude oil exports compared to January 2022. The fact that the calibrated model does not predict a large effect of supply and demand shifts on the global price of oil (or for that matter on Russian export prices) from January 2022 to March 2023 is consistent with the oil market having returned to some degree of normalcy at this point, following the surge and then decline in global oil demand in 2022.

The model also illustrates the effect of the dramatic shift in the destinations of Russian crude oil exports, as the EU embargo and related import restrictions segmented the oil market. Notably, about half of Russian crude oil exports are shifted to India, which as of January 2022 imported no Russian oil at all (see Table 6). At the same time, Chinese crude imports from Russia increase by 63%. Russian oil imports to the rest of the world drop sharply. This reallocation has little effect on global crude oil prices, however, consistent with the global export volume remaining roughly constant and Russia being forced to absorb the cost of shipping the oil to farther destinations. Table 6 shows that the Russian Urals fob price, p_U^*, would have dropped by $16/bbl due to the transportation cost increase alone, neglecting the change in Indian market

[22] Recall that there is no market segmentation in January 2022. To match the data, we force India's import from Russia to zero and satisfy India's entire demand by other suppliers. In return, China and other countries are assumed to take up the supply by Russia. Overall India's and China's share of demand and Russia's share of export matches the data.

Table 6: Decomposition of the Effects of Sanctions on Prices and Russian Export Flows

	Overall Change		**Supply & Demand Effect**		**Transportation Costs Effect**		**Market Power Effect**	
Crude Oil Prices	US$/b	%	US$/b	%	US$/b	%	US$/b	%
Market FOB price p_W^*	-8.45	-9.74%	-8.02	-9.25%	-0.81	-0.93%	0.38	0.44%
Urals FOB price p_U^*	-42.39	-48.87%	-8.02	-9.25%	-15.72	-18.12%	-18.65	-21.50%
ESPO FOB price p_E^*	-19.21	-22.15%	-8.02	-9.25%	-3.26	-3.76%	-7.93	-9.14%
Russian Crude Oil Quant.	b/d	%	b/d	%	b/d	%	b/d	%
Russian export	-274,130	-6.38%	-213,542	-4.97%	-25,420	-0.59%	-35,168	-0.82%
Indian import from Russia	2,097,165	n.a.	0	0.00%	2,122,564	n.a.	-25,399	-1.20%
Chinese import from Russia	709,895	58.42%	-40,606	-3.34%	760,270	62.56%	-9,769	-0.80%
Others import from Russia	-3,081,190	-100.00%	-172,936	-5.61%	-2,908,254	-94.39%	0	0.00%

power. The ESPO fob price would have dropped by $3/bbl in the absence of a change in China's market power.

Finally, consider the "market power" channel. While the curtailment of Western demand for Russian crude oil explains the large shifts in imports of Russian crude oil seen in the actual data, it does not help explain the price differentials for Russian crude oil relative to the world market prices observed in the data. This requires taking into account changes in India's and China's market power. Table 6 quantifies the extent of monopsony power of India and China in their respective markets for Urals and ESPO oil. The degrees of monopsony power are endogenously determined in the model calibrated to the March 2023 data. As expected, in the model both India and China withhold demand in order to wield their market power.[23]

As a result, we see the prices for Urals and ESPO oil and the world market price diverge in the model, much like in the actual data. The rest-of-the-world market price increases slightly by less than 1% due to the larger residual demand of India and China because these countries withhold some demand from Russia in order to exert some degree of market power. At the same time, the fob prices for Urals and ESPO crude oil decline substantially, as India and China exercise their partial monopsony

[23]It may seem counterintuitive at first sight that China and India would have been "withholding" some of their demand for Russian oil, given that China and India *increased* their imports of Russian oil over this period. The point here is that "withholding" means that India and China could have absorbed an even larger amount of oil from Russia than they did in the end, but chose not to. In other words, the relevant reference point is the oil market in March 2023 after accounting for both supply and demand effects and the transportation cost increases caused by sanctions-related market segmentation.

power in those markets. The Urals price drop by an additional \$19 and the ESPO price by an additional \$8. Thus, as in the actual data, transportation costs only account for about half of the observed price decline in the Urals fob price. The remainder is explained by India's market power. For the discount in ESPO oil prices, in contrast, market power is more important than transportation costs, consistent with the arguments in Section 4. The effect of India's and China's market power on export quantities is negligible compared to the effect of higher transportation costs.

It is noteworthy how close the price effects of the transportation cost and market power effects in Table 6 are to the back-of-the-envelope calculations in Section 4. Both approaches yield a combined increase in the Urals price discount of \$34. Based on the price data, the transportation cost was estimated to be \$15 compared to \$16 in the calibrated model. The market power effect was estimated to be \$17 compared to \$19 in the calibrated model. The overall effect on the ESPO price of \$12 in the data is also similar to the \$11 in the calibrated model. While we were unable to parse the effect of higher transportation costs and higher market power on the ESPO fob price in the empirical section, the calibrated model helps answer that question. It assigns \$3 to the added transportation cost and \$8 to China's higher market power.

This result does not require an implausibly high degree of market power. Table 4 shows that the parameters governing the monopsony power of India and China are, respectively, $\alpha_I = 0.87$ and $\alpha_C = 0.83$, which means that their monopsony power is similar and in the intermediate range. Full monopsony power would have implied α equal $\frac{1}{2}$ and no monopsony power α equal 1.[24] The result that both India and China have only *partial* monopsonist bargaining power in the Urals and ESPO markets, respectively, may be due to the fact that in reality both compete to some extent with each other for Russian oil in both markets despite the vast shipping distances between the Baltic Sea and China as well as the Pacific port of Kozmino and the West Coast of India. It might also be due to the fact that – unlike under our simplifying modeling assumption – other countries like Turkey and the UAE have at times competed for Russian oil. Finally, it might be due to the fact that the Urals and ESPO pipeline system is connected, if only imperfectly.[25]

[24] It appears that China has slightly more monopsony power in the ESPO market than India in the Urals market, which is surprising given that prices in the Urals market are much lower than prices in the ESPO market. However, we should not read too much into these small differences because α is a measure of monopsony power only when considering each market in isolation. In practice, India and China also interact with the (rest-of-the) world market and their monopsony power has an indirect effect on the world market through their residual demand.

[25] An alternative measure of the respective bargaining power of Russia, India and China is their threat-point, which is shutting down their respective segmented market. Either Russia or India may threaten unilaterally to shut down the Urals market, while either Russia or China may threaten unilaterally to shut down the ESPO market. Our model suggests that sizable effects on market prices in the world market from such actions. Neglecting transportation costs, the world market price would increase to \$95.59 and

Thus, not only is there no direct evidence for an important role of the G7 price cap in explaining the increase in the fob price discount, as shown earlier, but the decomposition in Table 6 indicates that the observed changes in oil prices and export quantities between February 2022 and March 2023 are fully predicted by a combination of shifts in global demand and supply unrelated to the sanctions and international restrictions on imports from Russia including the EU embargo, even in the absence of the price cap and in the absence of fraudulent transportation charges. As a result, the mere fact that not all of the increase in the fob discount can be explained by rising transportation costs is not sufficient evidence for fraudulent transportation charges.[26]

We are not the first to question the efficacy of the G7 price cap, of course, but we base thisargument on a formal analysis of the channels by which sanctions affect the Russian fob price. Our analysis provides an alternative explanation of the residual price spread of $17 documented in Section 4 that does not rely on fraudulent transportation charges. It also calls into question the view among some observers that the price cap explains the rise in the Russian fob price discount and the decline in Russian oil revenues in early 2023. Finally, it provides value added for those who are ready to concede that the price cap might have been ineffective, such as Hilgenstock et al. (2023), but who do not address the question of how to explain the evolution of the Russian fob price. The three mechanisms our analysis focuses on are new to the literature.

Of course, our model by itself merely illustrates that market power under reasonable assumptions could explain the residual increase in the Russian fob discount we documented in the data. Strengthening this conclusion requires additional empirical evidence. One additional implication of the market power model is that India's cif price for Urals oil should be below its cif price for oil from other producers. Assessing this question would require a comprehensive analysis of Indian customs data in March 2023, which is beyond the scope of the current paper. However, we can point to some tentative evidence that is in line with the calibrated model based on data for India's cif Urals price compiled by Cicala (2023). While this series ends before the embargo and price cap took effect, it allows us to assess the evidence for the time period of voluntary import restrictions in 2022. These data show that between 2018 and early

$94.17 per barrel with either the Urals or ESPO market shut down, respectively. World market prices would increase by 24% or 22% relative to prices without market power if the Urals or the ESPO market were shut down, respectively.

[26] It may seem that an alternative explanation for the reduction in the Russian fob price would be Russia lowering its price to accommodate Indian refiners that are not competitive in global markets at the prevailing price of crude oil imports. The argument is that Russia might lower its price to the point where these Indian refiners find it profitable to re-export Russian oil in the form of refined products, even if India has no market power. This argument ignores, however, that Russia does not have other buyers for its Urals oil. If it did, it would not care about uncompetitive Indian refiners, but sell its oil elsewhere. Thus, what is motivating Russia to lower its price in this example is Indian market power rather than Russian empathy.

2022, Urals oil was on average more expensive than other oil imported by India by $3, but starting in March 2022 it became less expensive on average by $6 for the remainder of 2022. This suggests that voluntary import restrictions in 2022 allowed India to lower the cif price of Urals oil by $9, consistent with the existence of non-negligible market power. While this estimate is lower than the $17 residual estimated for March 2023 (or the estimate implied by the model for March 2023), it does seem reasonable to expect India's market power to be higher after a formal oil embargo replaced the patchwork of voluntary import restrictions in 2022.

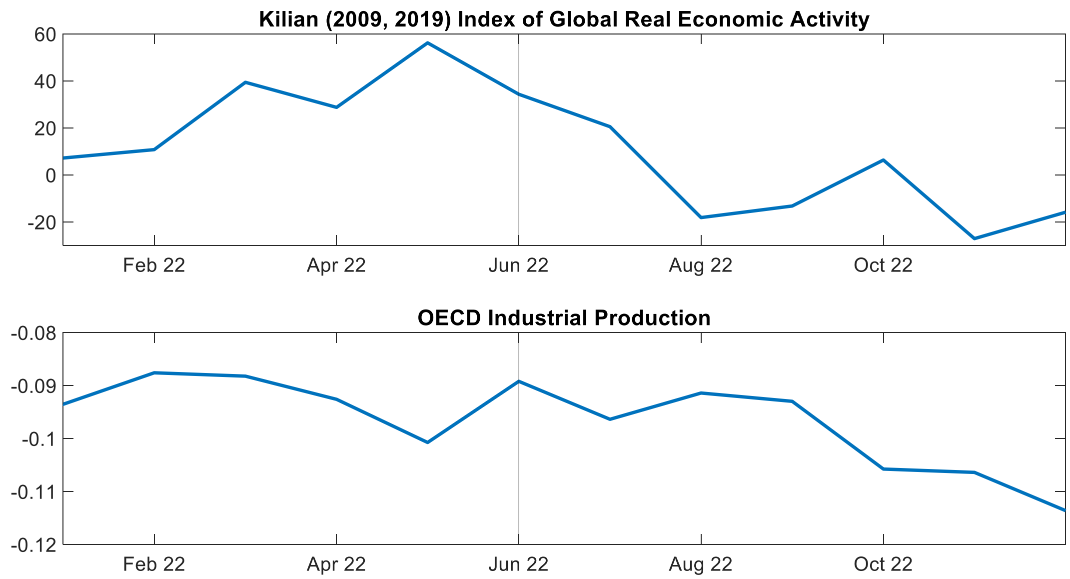
6 Did the oil market anticipate the price cap?

As noted in Section 3, another channel through which the price cap could potentially have reduced the global price of oil is by shifting down oil price expectations well before its implementation. In this section, we examine this hypothesis and find no support for this channel. On June 28, 2022, world leaders at the G7 summit discussed for the first time the need for an EU study of the feasibility of a price cap on Russian oil. In the G7 Leaders' Communique, they welcomed "the decision of the European Union to explore with international partners ways to curb rising energy prices, including the feasibility of introducing temporary import price caps where appropriate" (page 5). At question is how market participants viewed this statement, which influences the appropriate counterfactual against which to estimate the impact of the price cap.

If market participants viewed the G7 statement as a commitment to pursuing the price cap, and held the belief that such a policy would increase global supply (relative to the pre-announcement baseline), then one would expect oil prices to have fallen through the expectations channel (see Kilian and Murphy (2014)). That price decline would itself be attributable to the price cap, calling into question our earlier interpretation of the price decline being driven by a slowing global economy and unrelated oil supply shocks. Although the G7 wording fell far short of a commitment to a price cap, this hypothesis is worth investigating. One useful thought experiment is to hypothesize that markets did interpret the announcement as a forceful commitment. Next, we present suggestive evidence that even in that case the effects of the announcement would have been far smaller than the observed oil price decline.

As shown in Figure 4, the decline in the Brent price started 20 days before the G7 summit, on June 8, 2022, and there is no visual sign that the trend decline changed with this announcement. What about oil price expectations shifting around the time of the announcement? Such shifts should be reflected in the term structure of oil futures prices, even acknowledging the likely presence of a risk premium. If the oil price expected at the end of 2022 fell in response to news about a possible oil price

Figure 6: Indicators of Global Economic Activity in Commodity Markets



Source: Haver, FRED. The vertical line marks June 2022, the month of the G7 summit. OECD industrial production has been linearly de-trended.

cap, one would expect to see a downward shift in the futures price, especially for the December contract. Instead, the entire Brent futures curve (including the price of the December contract) shifted up on June 28 (or for that matter on June 29) relative to June 27, the day before the announcement. This evidence again argues against the view that the G7 announcement drove down the price of oil.

6.1 An alternative explanation of the decline in the price of oil

What about the alternative that demand for oil in the second half of 2022 declined substantially relative to the first half? There are several pieces of evidence consistent with this interpretation. One such indication is that the broad-based index of primary commodity prices compiled by the IMF peaked in mid-2022. It is widely accepted that such indices are proxies for fluctuations in global demand (see Kilian and Zhou (2018)). This evidence is broadly consistent with the evolution of the Kilian index of global real activity (see Kilian (2009), Kilian (2019)) that was designed to capture fluctuations in activity related to markets for industrial commodities (see Figure 6). This index leads fluctuations in real output by one month. It reached its peak in May 2022, ending a long expansion that started in 2021, when the Covid pandemic fizzled. The peak in May is followed by a sustained decline in the second half of 2022. Cruder proxies for variation in global real activity in commodity markets such as the OECD industrial production index also indicate a substantial slowing of the global economy in the second half of 2022, with a peak in June, at the same time as the price of oil. Thus, a plausible interpretation is that the upward trend in the Brent price in the first half of 2022 reflected strong and growing demand (with departures from this trend explained by the initial market response to the Russian invasion of Ukraine), while the trend decline in the second half of 2022 mainly reflected slowing demand for oil related to macroeconomic conditions rather than expectations of the oil price cap.

6.2 Other anticipatory effects of the price cap on the Brent price

A related argument for why the anticipation of the price cap may have mattered for the global oil price is that as of June 2022 there may have been a large premium in the price related to fears of a disruption of Russian oil supplies to the global market. This "fear premium" was alleviated only by the announcement that there might be a price cap at the end of the June. Thus, the apparent decline in global oil demand was not driven by the business cycle, but by the price cap.

This hypothesis does not appear to fit the data, however. Oil inventories persistently increased after June 2022 (see Figure 6 in Johnson et al. (2024)). This increase is inconsistent with a reduction in storage demand driven by lower oil price expectations because such a reduction should have lowered oil inventories. Thus, the inventory data provide no support for the hypothesis that the price cap was responsible for much of the decline in the Brent price in the second half of 2022 because it assuaged market fears about an oil supply disruption. Nor is there evidence of systematic destocking after the implementation of the price cap started in December 2022. An increase in oil inventories is consistent, however, with a persistent reduction in the flow demand for oil driven by a slowing global economy, as documented in our Figure 6 (see Kilian and Murphy (2014)).

Moreover, the narrative about higher oil supply expectations does not fit the data on the global business cycle in Figure 6. If there had been a substantial decline in the oil price driven by expectations of higher global oil supplies after June 2022, this should have stimulated the economy and raised global real activity. The steady decline in global real activity after June 2022 is difficult to reconcile with this hypothesis. In contrast, our alternative explanation that the oil price decline in the second half of 2022 reflected a slowing of global economic activity is consistent with the real activity data.

Finally, there is evidence of a fear premium driving the oil price away from its trend only in March 2022 (see Figure 4), consistent with the temporary surge in oil price uncertainty documented in Figure 2 of Kilian et al. (2024). This premium reflected anxiety about possible disruptions of global oil supplies, as widely discussed in the press. When this oil price uncertainty receded, the oil price reverted to the upward trend it had been on at the beginning of the year, casting doubt on the existence of a large fear premium in mid-2022 or later in 2022.

There is no evidence that the oil market in mid-2022 was particularly concerned about a possible lack of access to maritime services causing a shortage of oil and higher global oil prices. Had such concern existed, one would have expected a sharp response in the price of oil to the announcement of the 6th EU sanctions package dated June, 3, 2022. Figure 4 shows that no discernible response occurred.[27]

6.3 Does anticipation of the price cap explain the surge in the fob discount in late 2022?

Figure 4 shows that the Urals fob discount was largely flat in the first months of 2023. Yet another variation on the theme of anticipation is the argument that perhaps the price cap had no apparent effect on the Urals fob price discount in early 2023 simply because the shipping market already anticipated the imposition of the price cap as of late 2022, when the imposition of the price cap became imminent, causing the Urals fob price discount to reach its maximum before the price cap took full effect. While there is indeed a sustained increase in the Urals fob price discount in late 2022, as shown in Figure 4, that evidence cannot be explained by the price cap, given the simultaneous drop in the Urals fob price in late 2022 well below the price cap of $60 dollars.

A variation of this argument is that the transportation cost increased, regardless of whether the price cap was binding or not, because the stigma of having to deal with Russian companies caused Western insurers to withdraw from the market or to charge an insurance risk premium. A sharp rise in the insurance rate could, in principle, explain a decline in the Russian fob price. The problem with this explanation is that not only is there no stigma attached to shipping oil priced below the price gap, but insurance is only a small component of transportation cost, as discussed in Appendix A, and it would have taken an extremely large insurance risk premium to explain a

[27] The Brent price remained stable at $125 on the day after this announcement. It temporarily peaked one week after the announcement at $128, before resuming the decline that had started on June 8. Even if one were willing to attribute this delayed increase to the EU announcement, it stands to reason that the reaction to a likely removal of several millions of barrels of Russian oil from the market would have been more than $3, so we can safely rule out that explanation. Nor would allowing for the market to anticipate this announcement explain this puzzle.

large decline in the fob price that surely would have been reported widely in the press. There are no such press reports or any other evidence supporting this explanation.

A more plausible explanation is that the EU oil embargo expanded and EU oil imports from Russia declined further in November and December 2022, as documented in Figure 1, while oil exports to India (but not China) expanded. This redirection of trade flows is consistent with a sharp increase in the average shipping distance (and hence shipping costs) of Russian crude oil exports in November and December 2022, documented in Figure 7 of Hilgenstock et al. (2023). This further market segmentation in turn would also be expected to have raised India's market power as an importer of Russian crude oil.

7 Conclusions

A central question for policymakers has been whether the EU oil embargo and G7 price cap is working, and, if so, what components of these sanctions have proved effective and why. We provide evidence that the sanctions reduced Russian oil export revenues by 26% compared to the revenues that would have been expected in March 2023 given the global price of oil, which is much lower than conventional estimates. Our analysis shows that the success of these sanctions in reducing Russian oil export revenues owes more to the voluntary import restrictions in 2022 and the subsequent oil embargo than to the G7 price cap. Not only is the evolution of the Russian fob price for Urals crude in the first half of 2023 not consistent with a binding price cap, but the price cap appears to have done little to curtail Russian oil revenues in the second half of 2023, when the Urals fob price rose far above the price cap. The lack of enforcement of the price cap documented by Hilgenstock et al. (2023) means that there was at best a negligible risk premium compensating shippers in violation of the sanctions for the possibility that they may be caught. Nor did we find evidence that the announcement of a potential price cap in June 2022 altered global oil prices or market beliefs about future oil prices as measured by oil futures prices. Such an effect would also have seemed inconsistent with the decline in global real activity in the second half of 2022 and the fact that oil inventories persistently increased in the second half of 2022. Nor did they decline after the implementation of the price cap started in December 2022.

Evaluating the effect of the price cap requires distinguishing between its important political contribution of allowing those transporting Russian oil access to Western services, and its direct economic effects. While our analysis shows that the effects of the price cap on the Russian fob price have been negligible conditional on the West making available some maritime services for the transport of Russian oil to Asia, we are not saying that the economic outcomes in 2023 would have been the same if the price cap had never been implemented. Rather we acknowledge that the price cap helped reach a political consensus in Europe and likely helped prevent a surge in oil prices and a global recession. It also induced Russia to expand its shadow fleet, putting pressure on Russian budgets, although we discussed several reasons why some of this increase may have been caused by factors other than the price cap. Once the EU agreed to relax the maritime services ban, however, the price cap effectively had served its purpose and did not materially contribute to the Russian fob price discount in 2023. This distinction is at odds with common perceptions of the success of the oil price cap and matters for the design of future sanction policies because it suggests that a price cap is not an essential component of sanctions packages in general.

Instead, we stressed that Russia was forced to lower its fob price, as it diverted its crude oil exports to India and China, to accommodate the higher cost of shipping crude oil over longer distances. Moreover, as an oil export revenue-maximizer, Russia had no choice but to acquiesce to India's and China's insistence on lower prices for Russian crude, given the rising market power of the only remaining major importers of Russian crude. A calibrated model of the global oil market demonstrates that increased transportation costs and a modest amount of market power can explain the discounts that Russia was offering on its fob price relative to the global price of oil. Empirical evidence based on Indian cif prices supports the view that India had nonnegligible market power after the start of voluntary import restrictions. This evidence suggests that the oil embargo (and related import restrictions) were ultimately responsible for lowering the Russian fob price. The implications of our calibrated model closely match those of a back-of-the-envelope calculation based on detailed data for Russian fob prices, cif prices in selected importing countries, and commonly used oil trading benchmarks.

Our analysis provided an alternative to existing narratives that attribute the rise in the Russian fob discount to Russia's control of the transportation market for Urals, arguing that shipping and trading companies under the control of Russian oil companies overcharged Indian refineries, which raised the effective price of Urals exports far above the fob price. Proponents of this view argue that this is the only plausible explanation of the sharp increase in the fob discount for Urals oil relative to Brent, even if there is no direct evidence supporting it. We showed that there is an alternative explanation that - unlike earlier narratives - does have some empirical support and can explain why the Urals fob price fell well below the price cap in early 2023.

Our model provides evidence that the price discount on Russian oil in March 2023 was mainly due to the import restrictions culminating in the EU oil embargo, which were reflected in a rise in transportation costs and in India's and China's market power. As long as the oil embargo continues to be enforced, all else equal, one would expect the price discount to persist. The fact that the price discount on Urals oil has steadily declined since March 2023, as shown in Figure 4, raises the question of what has changed.

While a formal examination of this period is beyond the scope of this paper, in our view, the erosion of the Russian fob discount since March 2023 is likely explained by several changes in market conditions. For starters, Russian seaborne crude oil exports declined by 20% between March 2023 and November 2023. This decline arguably reflected in part Russia's commitment to OPEC+ production restrictions and in part the lower efficiency of Russia's oil industry. As less oil was being exported by sea, the demand for oil tankers fell and so did the cost of transporting crude. The reduction in seaborne transportation costs, which has also been reflected in a declining spreads between the Russian fob and the Indian cif price of Urals oil after March 2023, in turn helps explain the lower Russian fob price discount relative to Brent.

The fall in Russian oil exports may also have been driven by lower demand from India. From March to November 2023, India reduced its demand for Russian oil by 13%. This was not a consequence of the threat of G7 sanctions, but likely caused by some combination of lower domestic demand for oil, limits to oil storage, and a reduction in India's ability to re-export refined products profitably. There was no material decline in China's oil demand for Russian oil over the same period. Finally, Russia has also become more adept at bypassing embargo restrictions by disguising the origin of its oil exports, which reduces the market power that was previously enjoyed by India and China, as does the recent increase in Turkey's oil imports from Russia. Turkey's imports doubled between March and November. Much of this oil finds its way into Europe directly or indirectly, undermining the oil embargo.

While it is conceivable that tightening the enforcement of the price cap could substantially improve its effectiveness, such measures are not likely to stem the flow of ESPO crude from Russia to China short of imposing secondary sanctions on Chinese companies, which may or may not be politically feasible. There is more scope for reducing the size of the shadow fleet supplying Urals oil to India. However, the second phase of the price cap launched in October 2023, in an effort to enhance compliance and to increase the costs to Russia of using the shadow fleet, had little effect on the fob price discount for Russian Urals oil relative to Brent. The discount was $13 per barrel in September 2023, before the enforcement was tightened. By February 2024, it had increased only by a few dollars to $17, with the Urals price remaining above the price cap of $60. This situation may change after the U.S. Treasury considerably tightened the enforcement of the price cap in early 2025. Preliminary indications are that enforcement may have started in earnest this time.

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Online Appendices

A The Tanker Insurance Premium

The cost of insuring oil tankers carrying Russian crude depends not only on the distance travelled, but also on the availability of insurance from non-Western providers and on whether the tanker passes through a war zone. Tanker insurance rates reflect the cost of insuring the cargo of crude oil as well as the cost of insuring the tanker itself, also known as hull insurance. There is an insurance premium when tankers travel through a war zone. For example, in 2019, after six oil tankers had been attacked in the Persian Gulf, the cost of insuring crude oil cargoes from the Middle East rose tenfold to reach 0.4% of the price of crude oil, reaching 25 cents of the Brent price of $64.30 per barrel at the time (see Tobben (2019)). As far as insurance for the tanker itself is concerned, a plausible war risk premium might be two percent of the market value of the empty vessel for seven days of coverage. Therefore, for a tanker worth $100 million transiting the war zone, the war insurance premium would be two million dollars. Assuming a cargo of two million barrels of oil, this amounts to a one dollar increase in the price per barrel. The combined increase in insurance costs in this example is associated with little more than a $1 increase in the price per barrel of oil. This illustrates that the cost of oil tanker insurance tends to be negligible relative to the price of crude oil, even under war-like conditions.

A similar surge in hull insurance premia took place in 2022, as the invasion of Ukraine unfolded and even neutral oil tankers operating in the Black Sea were increasingly at risk. Saul (2022) reports that the hull insurance rate for tankers in the Black Sea for a 7-day period increased from 0.025% before the invasion to between 1% and 5% after the invasion. This puts the hull insurance for an Aframax tanker at between $0.88/barrel and $4.38 per barrel. By April 2022, the hull insurance premium for a $50 million, five-year old tanker hauling a standard one million-barrel Russian cargo was about $5/barrel (see Koh et al. (2022)). By May 2022, hull insurance premia for oil liftings from the Black Sea had increased four-fold compared to before the invasion (see Paris (2022)). Information on cargo insurance premia is harder to come by, but tends to be an order of magnitude smaller, as illustrated by the earlier Middle Eastern example. According to Reuters, the war risk premium for vessels in the Black Sea increased by 20% in early 2023 (Ollett and Bhattacharjee (2023); Saul (2023)).

These insurance premia, however, only apply to Russian crude exports from the Black Sea which account for only 16% of all Russian oil tanker exports. The remaining 84% of Russian oil tanker exports from Baltic, Arctic and Pacific ports were not affected by this development. A further unrelated increase in insurance premia likely took place after the imposition of the price cap in December 2022. While the price cap does not prevent tankers from carrying Russian cargo to third countries, to the extent that some insurance providers withdrew from the market rather than becoming involved in verifying the price cap, it arguably may have raised the cost of obtaining Western maritime insurance for tankers carrying Russian oil under the price cap exemption. Argus reported that tanker insurance rates, after the imposition of the price cap, were expected to increase by 4 percent in 2023 (see Ollett and Bhattacharjee 2023). Not only is this increase quite modest, but these higher rates do not apply to all tankers carrying Russian oil, suggesting that the tightening of the insurance market does not materially affect our interpretation of the changes in the cif-fob spread for Urals crude oil.

Nor was access to insurance services a concern. Oil cargoes that are actually (or ostensibly) sold below the fob price cap of $60 per barrel in early 2023 accounted for nearly 60% of all tankers carrying Russian oil cargoes, according to Nightingale et al. (2023). Subsequent research based on transactions data in Hilgenstock et al. (2023) shows that virtually all Urals oil was exported at prices well below the price cap in the first quarter of 2023, allowing most tankers unlimited access to Western insurance. Even for the few remaining tankers not relying on Western insurance, the cost of insurance need not have increased. For example, it seems quite plausible that some of the alternative insurance providers active in this market charge less than Western insurance companies because the coverage of their contracts is lower and payouts are less certain. This is certainly the case for the state-owned Russian tanker fleet.

Non-state-owned oil tankers operating in violation of the price cap also have access to Russian maritime insurance. While this insurance is arguably less comprehensive than its Western counterpart, it is accepted by Denmark for passage through the Denmark Strait, by Turkey for passage through the Bosporus Strait, and by Egypt for passage through the Suez Canal. Moreover, there is no evidence of a war risk premium for Russian owned tankers operating from the Black Sea, and, to the extent that foreign tankers move crude oil from the Black Sea in violation of the embargo, they often take delivery of Russian cargoes outside of the Black Sea by ship-to-ship transfer, obviating the need to pay a war insurance premium.

While information about the insurance market for Russian oil cargoes is fragmentary, it is clear that the added cost of insuring Russian oil cargoes and insuring oil tankers crossing the Black Sea is small, on average, relative to the price of crude oil in global markets. Thus, we abstract from changes in oil tanker insurance costs. It should be noted that this situation may change if the price cap is lowered or if its enforcement is substantially tightened, but this was not the case in 2023 or in 2024, and our main concern in this paper is with understanding the data through 2023.

The discussion in Section 4 attributed the increased wedge between fob and cif prices in March 2023 to the higher transportation costs associated with shipping Urals oil over longer distances including the rise in tanker rates from the reduction in the effective size of the tanker fleet. As noted by Kennedy (2023), however, there is another possible explanation of rising transportation costs. The argument is that the price cap created a risk premium for companies involved in shipping Russian oil in violation of the price cap (and possibly for companies concerned with inadvertently running afoul of the rules and being held responsible despite shipping Russian oil nominally valued under the price cap), which was reflected in higher insurance costs. Kennedy's interpretation of the data on transportation costs for Urals crude oil is that this risk premium was high in early 2023 and came down in the second half of 2023, as evaders of the price cap became less concerned that they would be caught and sanctioned. Kennedy (2023) also makes the case that the risk premium may have risen again after the U.S. Treasury started tightening the enforcement of the price cap in October 2023.

One obvious challenge with this argument is the difficulty of measuring such an insurance risk premium and of establishing that it moved as conjectured. There have been no press reports about such an insurance risk premium, which is noteworthy since it would require an extremely large increase in insurance costs to substantially lower the Russian fob price, which surely would have attracted attention. Moreover, we can deduce that the decline in the Russian fob price below the price cap in the first half of 2023 is unlikely to be explained by such a risk premium because, as soon as the fob price falls below the price cap, the risk of being sanctioned and therefore the risk premium goes to zero. This means that the existence of a risk premium would have bounded the Russian fob price from below by the price cap of $60. The bulk of Urals transaction prices clearly was not anywhere near the price cap in March 2023 (see Figure 3 in Hilgenstock et al. (2023)).

While we do not formally examine what happened in the second half of 2023, when the Russian fob price systematically exceeded the price cap, there is no indication of a quantitatively important shipping risk premium in the second half of 2023 either. In fact, analysis by Hilgenstock et al. (2023) suggests that the effective compliance with the price cap was poor. There is general agreement that the risk of violators of the price cap being caught was low at this point and that violations of the price cap had become widespread. Indeed, it was this fact that prompted the U.S. Treasury to attempt to tighten the enforcement of the price cap in October 2023 and again in January 2025. It remains to be seen whether tightened enforcement of the price cap will change this situation.

B Calibration of the "After Sanctions" Model

This appendix provides further details on the "After Sanctions" Model and its calibration. First, we derive equation (2). Assume first that India has full monopsony power. Then India chooses the quantity of Urals imports to maximize her gross surplus minus cost:

$$\max_{q\in\mathbb{R}_+}\left(\frac{d_I^{-1}(0)-d_I^{-1}(q)}{2}q+d_I^{-1}(q)q-(s_U^{-1}(q)+t_U)q\right).$$

The first two terms are India's gross consumer surplus. The last term are the import costs.

Expand and simplify this expression to obtain

$$\max_{q\in\mathbb{R}_+}\left(\frac{1}{2}\left(d_I^{-1}(0)q+d_I^{-1}(q)q\right)-s_U^{-1}(q)q-t_Uq\right).$$

The first-order condition is

$$\frac{1}{2}\left(d_I^{-1}(0)+d_I^{-1}(q_U^*)+\frac{\partial d_I^{-1}(q_U^*)}{\partial q}q_U^*\right)=s_U^{-1}(q_U^*)+\frac{\partial s_U^{-1}(q_U^*)}{\partial q}q_U^*+t_U, \tag{5}$$

which is India's marginal gross consumer surplus equals India's marginal cost.[28]

India's inverse demand and Russia's inverse supply of Urals crude oil are, respectively,

$$\begin{aligned}
d_I^{-1}(q)&=\frac{\ell}{m}-\frac{1}{\gamma_I m}q\\
s_U^{-1}(q)&=-\frac{c}{k}+\frac{1}{\rho_U k}q.
\end{aligned}$$

Thus, the l.h.s. of equation (5) becomes

$$\begin{aligned}
\frac{1}{2}\left(d_I^{-1}(0)+d_I^{-1}(q_U^*)+\frac{\partial d_I^{-1}(q_U^*)}{\partial q}q_U^*\right)&=\frac{1}{2}\left(\frac{\ell}{m}+\frac{\ell}{m}-\frac{1}{\gamma_I m}q_U^*-\frac{1}{\gamma_I m}q_U^*\right)\\
&=d^{-1}(q_U^*),
\end{aligned}$$

and equation (5) is equivalent to

$$\begin{aligned}
d^{-1}(q_U^*)-t_U&=s_U^{-1}(q_U^*)+\frac{\partial s_U^{-1}(q_U^*)}{\partial q}q_U^*\\
&=-\frac{c}{k}+\frac{1}{\rho_U k}q_U^*+\frac{1}{\rho_U k}q_U^*\\
&=-\frac{c}{k}+2\frac{1}{\rho_U k}q_U^*,
\end{aligned}$$

[28] We use ∂ in place of d to avoid confusion with the demand function.

which after some algebra is equivalent to

$$\frac{1}{2}\rho_U\left(c + k\left(d^{-1}(q_U^*) - t_U\right)\right) = q_U^*$$
$$\frac{1}{2}s_U(d^{-1}(q_U^*) - t_U) = q_U^*.$$

Using $q_U^* = s_U(p_U^*)$, we obtain

$$\frac{1}{2}s_U(d^{-1}(s_U(p_U^*)) - t_U) = s_U(p_U^*).$$

When India has no market power, the effective price $d^{-1}(s_U(p_U^*))$ must equal the competitive cif price. In this case, $d^{-1}(s_U(p_U^*)) - t_U = p_U^*$ is the competitive fob price for Urals oil, and

$$s_U(d^{-1}(s_U(p_U^*)) - t_U) = s_U(p_U^*)$$

must hold. Thus, for any degree of market power $\alpha_I \in \left[\frac{1}{2}, 1\right]$, equation (2) holds:

$$\alpha_I s_U(d^{-1}(s_U(p_U^*)) - t_U) = s_U(p_U^*).$$

Equation (3) can be derived analogously.

The system of equations is given by equations (2) to (4) and

$$\rho_U s(p_U^*) = q_U^* \tag{6}$$
$$\rho_E s(p_E^*) = q_E^* \tag{7}$$
$$s(p^*) = d^*(p^* + t) \tag{8}$$

together with the identities

$$-m = e_D(p^*)\frac{q^*}{(p^* + t)} \tag{9}$$
$$k = e_S(p^*)\frac{q^*}{p^*}, \tag{10}$$

given the data realizations in the lower part of Table 3 and $p^* \geq 0$.

Solving for the unknowns $\{p^*, q^*, \gamma_I, \gamma_C, \rho_U, \rho_E, \alpha_I, \alpha_C\}$ also determines the parameters m, ℓ, k, and c. Note that (p^*, q^*) is the competitive equilibrium in the counterfactual market without sanctions. The parameter t is the cost of insurance and freight in the counterfactual market without sanctions, which we assume to equal the costs prevailing in January 2022. We set t_U (the cif-fob Urals markup), t_E (the cif-fob ESPO markup), and t_W (the cif-fob markup in the rest of the world for the segmented market in March 2023), to the values stated in Table 3. The parameter solutions $\gamma_I, \gamma_C, \rho_U$, and ρ_E should be understood as the "true" but unobservable market shares of India, China, Urals, and ESPO, respectively, in the competitive equilibrium of the counterfactual market without sanctions. The results of the calibration are shown in the third column of Table 4.