Crisis Management in the Russian Oil Industry: the 1905 Revolution

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INTRODUCTION

Many countries of the world, including the United States, are becoming increasingly dependent on foreign supplies of petroleum. This trend is of concern because, among other things, much of the petroleum available on the world market is produced in nations which have been subject to violent internal upheavals since World War II. As examples, Indonesia experienced a communist revolt in 1965, Nigeria was racked by civil war from 1967 to 1970, Libya's government was overthrown in 1969, and Iran has experienced severe upheavals since 1978.

Given the unsettled state of many of the petroleum exporting countries, it behoves importing nations to consider the possible consequences of future upheavals in the nations which supply them with this vital product. While it may be possible at some future date to develop a general theory covering the results of such disorders, study of the problem is at such an early stage now that it is more appropriate to begin by examining particular cases and to leave generalizations to a later time.

The purpose of this paper is to present a case study of the consequences for producers and, to a lesser extent, users of petroleum products of the general strikes and violence which occurred in Russia during 1905. Russia is a particularly appropriate subject for study because at the time it was the world's second largest producer and exporter of petroleum.

The study concentrates on adjustments to the crisis *within* Russia and is organized as follows. Part I presents a description of the development and organization of the industry, while Part II provides information on the 1905 revolution. Adjustments during the crisis itself are covered in Part III, while the process of recovery (1905-1907) and long run responses to the crisis (1905-1913) are examined in Parts IV and V, respectively. Part VI provides a discussion of the findings and tentative conclusions. Finally, a new series on crude oil prices is presented in the Appendix. The discussion is limited to the consequences of the upheaval for the Russian Empire and has little or nothing to say about effects on the outside world. The latter topic hopefully will be addressed in a later paper.

I

Description of the Oil Industry

Growth of the Industry

During the Tsarist period most of the petroleum production within the Russian Empire took place near Baku, a city on the west coast of the Caspian Sea which had been acquired from Persia through the Treaty of Gulistan (1813).

The Tsarist government took over the existing naphtha pits of Baku and exploited them as a source of government revenue, either operating them as a state enterprise or farming them out in a block to the highest bidder.

In 1872 the Tsarist government turned away from these monopoly approaches and made much of the oil-bearing land available to private firms under a variety of long-term arrangements. Under the influence of this shift to competition and a series of innovations in methods of extraction, distribution, and utilization of petroleum products, prices of crude oil fell sharply and sales expanded. Between 1872 and 1892 the price of crude fell from 45 copecks per pood to 1.1 copecks per pood and production rose from 1,536,000 poods to 287,800,000 poods per year.[1] Production of crude oil during the Tsarist period reached a peak in 1901 (706.0 million poods) and then declined, averaging only 563 million poods per year from 1902 through 1917. [Kelly and Kano, Tables 3 and 4].

Uses of Petroleum Products

At first there was little interest in any of the products refined from crude oil except kerosene which found a market as an illuminant at home and abroad. The residual left from the refining process — *astatki* — was considered a nuisance and was burned in open pits to get rid of it. But in the 1860's Aydon and Shpaovsky both developed methods for combusting *astatki*, and in the early 1870's Shpakovsky succeeded in equipping a Caspian Sea steamer with oil-fired engines. *Astatki* was adopted by other steamers and in the 1880's began to be used by some of the Russian railways and by industrial plants in the Volga region. [Marvin, pp. 300-301, 262-68; Thompson, p. 8].

Although other products were produced from crude oil, kerosene and *astatki* accounted for about 90 percent of all petroleum shipments from Baku (by weight in 1902). [Thompson, p. 14].

Distribution of Petroleum Products: The Volga Route

Before the Transcaucasian Railway was opened in 1883, the Russian market was served largely by water transportation. Crude

[1] One pood = 36.11 lb.; 100 copecks = one rouble.

oil and refined products were shipped from Baku on the Caspian Sea up to Astrakhan at the mouth of the Volga River and thence northward up the river. Because of the great length of the Volga and its tributaries (over 19,000 navigable miles), large areas of the country could be reached by this route including the Volga ports of Tsaritsyn, Saratov, Kazan, and Nizhny-Novgorod; ports along the Kama River; Moscow; and — via the canals linking the Volga with the Neva River — St. Petersburg and various ports along the Gulf of Finland and the Baltic Sea. [Miller, p. 203; Chambers (1887), p. 411; Kovalevsky, p. 341].

Kerosene was originally transported either in barrels or in tins of four gallons each, packed in twos in wooden cases. But Robert and Ludwig Nobel, brothers of the inventor of dynamite, soon saw the potential of bulk transport and placed the first tanker in service in 1879. [Marvin, p. 290; Gerretson, pp. 211-12; Redwood, p. 79]. The number of tank steamers rose rapidly, reaching 18 in 1885, 34 in 1899, and 126 in 1902. While some of this growth was at the expense of sailing vessels, the total capacity of the oil transport fleet expanded to 12.0 million poods in 1902. [Thompson, p. 27].

At the roadstead south of Astrakhan the oil was pumped into shallow draft barges which then were towed by small steam tugboats to Astrakhan where the oil was transferred into river vessels or placed in storage. [Henry, p. 244; Thompson, p. 28; Chambers (1887), p. 411].

The transfer at Astrakhan and subsequent shipment to the interior of Russia was greatly affected by the seasons. Owing to the severity of the winter, water transportation of goods was impossible for part of the year. In the southern part of Russia it ceased for about four months between November and March while in the northern parts waterways might be closed from October to May. [Gerretson, p. 212; Miller, p. 177; Redwood, p. 80; Thompson, p. 27]. As a result, products would have to either be stored until spring or moved by land — an expensive proposition before the railroad. [Metzer, p. 534]. The seasonality problem was further intensified by seasonality in the demand for illuminating oil, which fell to low levels during the long summer days. [Marvin, p. 297].

The railroad brought an alternative means of transport which served to reduce the problem of seasonality in petroleum distribution. In 1851 St. Petersburg was linked to Moscow by rail and in 1862 Moscow in turn was linked to the northern Volga port of Nizhny-Novgorod. More important, though, was probably the linking to Moscow of Volga ports further to the south such as Samara (1877), Saratov (1871), and Tsaritsyn (1871). [Westwood, p. 302].

Tsaritsyn was well situated for petroleum distribution and became the transhipment point for most oil products going to the interior of Russia. By 1907 Tsaritsyn had 119 storage tanks with a total capacity of about 11.6 million poods. Petroleum products were transferred from these storage facilities to railroad tank wagons or barrels and shipped into the interior of Russia on the Tsaritsyn-Gryazye Railroad. [Gefter, p. 65; Thompson, p. 29; Redwood, p. 80].

Further up the Volga there were smaller storage and distribution points at Saratov, Kazan, and Nizhny-Novgorod. [Chambers (1887), p. 411].

Distribution of Petroleum Products: The Black Sea Outlet

With the expansion of production and the sharp fall in wellhead prices after 1872, there was increasing interest in exporting petroleum. However, export via the Volga water route to St. Petersburg and the Baltic was slow and expensive. Attention was therefore directed to schemes for shipping oil products across the Caucasus Mountains to the Black Sea.

The inherent difficulties of this route may be judged from the fact that in the early 1880's Tiflis, which lies about half way between the Black and Caspian seas and only 341 miles from Baku, used American illuminating oil which had been carried more than 8000 miles, rather than Russian oil. [Henry, pp. 112-13].

Mendeleyev, the famous Russian scientist, urged that a pipeline be built to transport crude oil which would then be refined at Batoum on the Black Sea. [Gerretson, p. 213]. His suggestion was rejected, though, and in 1883 a 560 mile railroad from Baku to Batoum was opened. [Chambers (1887), p. 414]. Batoum quickly became a major outlet for Baku petroleum and the second largest port in southern Russia (after Odessa). [U. S. DCL (1907), p. 39].

Before long the railroad was unable to handle the growing volume of oil traffic and the industry began to agitate for a pipeline across the Caucasus. The Russian Government resisted these entreaties at first for fear of financially undermining the railroad, but finally acquiesced in 1897. When the Baku-Batoum pipeline was opened in 1905 it could transport about 65 million poods of kerosene per year (about as much as the railway could carry a few years before). [Thompson, pp. 29-30].

Finally, some petroleum products were carried from Baku to Novorossisk on the northern coast of the Black Sea after a branch of the Vladikavkaz Railway was opened between Baku and Petrovsk in 1900. [Henry, p. 142].

II

The 1905 Revolution

The 1905 Revolution marked the high point of several years of disorders and was the result of a number of problems which came together at one time. Peasants caught between the pressures of growing rural population and backward technology were hungry for more land. Workers wanted higher pay, better working conditions, and the right to form labor unions. Middle class elements and even much of the nobility wished to see the social and economic system reformed. Social democrats and other radicals hoped to see the Tsarist Regime overthrown and the march toward inevitable socialism carried on under a bourgeois government. To this collage of conflicting desires was added the shame and confusion engendered by repeated defeats in the war with Japan. [Clarkson, pp. 376-79].

The revolution was made almost inevitable when Father Gapon's attempt to petition the Tsar peacefully on behalf of Petersburg workers was met by police and troops who killed or wounded hundreds of the petitioners. The news of "Bloody Sunday" (January 22) spread rapidly and by the end of January over 400,000 workers had gone out on strike.[2] The following months were marked by more strikes and by the famous June mutiny on the battleship *Potemkin* in the Black Sea. [Harcave, pp. 411-12].

In early October the typographical workers struck in Moscow and Petersburg. This was followed by a strike of railway workers which spread rapidly from Moscow until by the end of October almost the entire rail system and much of the Russian economy had come to a halt. [Trotsky, pp. 88-91].

Under mounting pressure, the Tsar issued a manifesto on October 30 promising reforms. There was a pause in the disorders until the workers began to regard the promised reforms as a ploy. Another general strike was called on November 15 in support of rebellious soldiers and sailors at the Kronstadt naval base who were threatened with execution. The Government agreed to make concessions on the question of the mutineers and by November 21 the general strike was over. [Clarkson, p. 387].

A final general strike was called on December 20 in Moscow.

[2] Unless noted otherwise, dates are given according to the Gregorian calendar (i.e., "new style") rather than according to the Julian calendar which was in use in Russia at this time and which was 13 days behind the Gregorian calendar.

As in October and November, a widespread shutdown of the rail system occurred. An armed insurrection ensued in Moscow and lasted for 9 days (December 22-30), but was ultimately put down. [Trotsky, pp. 234-46].

In 1906 strike activity declined substantially, though remaining at the highest level for any year before 1905. [Clarkson, pp. 388-94].

The Violence in the Caucasus

The Baku disorders really began in July, 1903, when strikes broke out in the oil fields. Although these strikes were mainly economic, they soon took on a political aspect as unruly elements set fire to derricks and attacked the homes of certain managers. The strikers won many of their demands and returned to their jobs with a new sense of power. [Thompson, p. 36; Villari, p. 192].

The next year — 1904 — was not marked by overt violence, but by a simmering undercurrent of mistrust and agitation. Representatives of the Tsarist Government encouraged the Tartars, who were Moslems, to believe that the Armenians planned to rise up and annihilate them and armed them for their own defense. [Henry, pp. 153-54; Villari, pp. 192-93]. Intermixed with native hostilities were legitimate labour people who were hoping to organize the petroleum workers and radical elements, such as the Social Democrats, who were probing for weak points in the social structure.

December of 1904 brought another strike and a 30 million pood reduction in crude oil production. [Henry, p. 250].

In February, 1905, violence broke out between the Tartars and the Armenians. Four days of slaughter, during which the Tsarist authorities either sat passively or encouraged the Tartars, saw the deaths of 300 to 400 persons, most of whom were Armenians. [Henry, pp. 153-63; Villari, p. 195]. During the following months the violence subsided, but did not disappear.

Early in September the Baku volcano empted and the Armenians and Tartars began to butcher one another again. This time the authorities did not sit idle. General Fadeieff was soon able to restore order within the city of Baku, but was less successful in the outlying areas where the oil fields were located. Residents of surrounding Tartar villages attacked many of the oil fields, paying particular attention to property owned by Armenians. Bands of Tartars roamed from field to field tracking down Armenian workmen and murdering them. [Henry, pp. 179-206; Villari, pp. 201-03].

From September 2 to about September 10 the violence raged out of control. But eventually, with the aid of reinforcements (including artillery), order was restored. [Henry, pp. 205-10; Villari, p. 203].

The disorders did not end at any definite point in time, but went on for a long period. Bloodshed continued right up to the end of September. [Henry, p. 214]. The railroad strikes in November and December were observed in Baku and slowed the recovery of the industry. [Villari, p. 207]. Although the following years were calmer, strikes, violence, and extortion continued to mar life in Baku.[3] [Thompson, p. 27; Ingalls (1907), p. 767].

Estimates of the Damage

The violence of September, 1905 did a substantial amount of damage to the Baku oil fields and initial extimates of the financial losses reached the alarming figure of £ 15,000,000.[4] But in time, after producers and others examined the situation more closely, estimates settled into a range of £ 2.0 million to £ 2.6 million. [Villari, p. 206; Henry, p. 216].

The damage proved to be less than at first imagined for

[3] In the first 9 months of 1907 time lost due to strikes is said to have averaged over 30 days per well. [Ingalls (1907), p. 767].

[4] Thompson (p. 397) gives an exchange rate of 9.45 roubles = £ 1 sterling.

several reasons. First, a substantial part of the cost of producing oil — exploration costs — is not lost unless the oil deposits themselves are lost. Second, the oil deposits and underground investments, being far below the surface, tend to be relatively protected from violence on the surface.[5] What tend to be destroyed are items on the surface: derricks, buildings, machinery, surface reservoirs of crude, etc. Third, part of the surface damage at Baku was to equipment or facilities which were old or obsolete and likely to be replaced within a few years. [Villari, pp. 206-07; Ingalls (1905), p. 477].

Nonetheless, the financial loss was substantial. Table 1 presents estimates prepared by the Government and by the producers, respectively, Based on what Ingalls (1905) reports, the higher producer estimates must be due to inclusion of subsurface destruction (ignored in the Government estimates) and higher estimated replacement costs of items. Wooden derricks constituted almost half of the estimated loss because of their number, their accessibility for rioters, and their flammability. [Ingalls (1905), pp. 477-78; Villari, p. 201].

Let us turn to physical measures of the destruction. According to Henry, 1026 operating oil wells were " destroyed " as were another 838 unabandoned wells.[6] Table 2 shows the percent distribution of the 1864 total wells destroyed, by oil field and status of the well before the fires. From the last row of the table it can be seen that 55.0 percent of the wells destroyed had been producing before the violence. However, the potential impact on production was slightly higher since the 1026 operating wells

[5] The extent of subsurface damage is open to some debate. Ingalls (1905) reports that producers claimed " considerable damage " was done below ground: " The pipes of the wells in many cases were stopped up by foreign bodies and half-burnt wreckage, which will delay the resumption of operations some time. Some 7,000,000 rubles must be added to cover loss from these causes." [Ingalls (1905), p. 478].

[6] Henry, p. 215. It is evident from other information that many of these " destroyed " wells were repairable at reasonable cost and did return to service.

destroyed had been accounting for 59.7 percent of monthly production. [Henry, p. 215].

Finally, there was an unknown degree of destruction of human capital in the industry through the murder of labourers and skilled workmen.

TABLE 1

FINANCIAL ESTIMATES OF THE DESTRUCTION AT BAKU OIL FIELDS
(pounds sterling)

Type of Loss	Producers' Estimate	Government Estimate	Percent (Producers)
Derricks	£ 1,209,900	£ 1,246,300	46.7
Workshops	175,700	74,400	6.8
Boiler-houses	110,600	24,000	4.3
Dwellings	272,000	194,000	10.5
Tanks	158,300	96,900	6.1
Material stores	250,600	57,500	9.7
Pipe lines	198,700 [a]	93,300	7.7
Various structures	81,200	55,600	3.1
Petroleum products	134,600	134,600	5.2
Total	2,591,600	1,976,600	100.1 [b]

a) Henry shows 108,700, evidently a typographical error.
b) Does not sum to 100.0, due to rounding.

Source: Henry, p. 216.

TABLE 2

PERCENT DISTRIBUTION OF OIL WELLS
DESTROYED, BY FIELD AND PRIOR STATUS OF THE WELLS
(n = 1864)

Field	Drilling Repairing, and Deepening	Temporarily Idle	In Operation	Status Unknown	Total
Balakhany	4.3	6.4	21.9	1.4	34.1 [a]
Sabunchi	11.4	10.2	21.7	0.3	43.6
Romany	2.4	2.0	5.0	—	9.4
Bibi-Eybat	5.2	0.9	6.3	—	12.4
Zabrat	—	0.4	0.1	—	0.4 [a]
Total	23.3	20.0 [a]	55.0	1.7	100.0 [a]

a) Does not equal row or column sum, due to rounding.

Source: Calculated from Henry, p. 215.

III

ADJUSTMENTS DURING THE CRISIS (1905)

Price Movements in 1905

The timing and anatomy of the crisis can be better appreciated if one examines the movement of crude oil prices at Baku during 1905. Prices were relatively stable from January through March, moving in a range of 13 ¼ to 15 copecks per pood, with no clear trend.[7]

From the end of March prices began to rise at an irregular, but accelerating rate. Prices are not available for the weeks of September 4, 11, and 18, but when price quotations again appeared — for the week of September 25 — they were about 50 percent higher than the last recorded prices. It was at this point that a correspondent for the *London Times* wrote from Moscow of fears that a large number of Volga steamboat companies, private railroads, and much of the mill industry of Moscow would be ruined by the shortages and high prices of astatki. [U. S. DCL, No. 300, p. 180].

In September this pessimistic prognosis was probably not uncalled for. But prices soon began to fall sharply until by December they were back to levels which had prevailed in June. Although prices did peak at twice the average for the year, the most severe part of the crisis appears to have been short-lived, lasting for only a matter of weeks.

The balance of this part of the paper will examine the ways in which the industry coped with the crisis and the reasons why it was not more severe.

Fortuitous Circumstances of the Crisis

The disruption of marketing and use was not as serious as it might have been because of certain fortuitous factors, includ-

[7] These weekly price quotations are taken U.S. DI (1905), p. 901.

ing characteristics of the petroleum marketing system, characteristics of the disorders, and the timing of the violence.

Prominent among industry characteristics were the destinations and principal transportation modes of the major products. *Astatki* was produced primarily for domestic users such as Volga River shippers, industrial plants along the Volga, and certain of the railroads. In 1902, 98.2 percent of the *astatki* produced in Baku left by sea and 93.7 percent found its way at least as far as the Volga port of Astrakhan. By contrast, only 1.4 percent of the *astatki* left Baku directly by rail. [Thompson, p. 14].

As a result, the movement of *astatki* in 1905 should not have been greatly disrupted until it reached a point in the distribution network where it had to move by rail (e. g., from a Volga port to an inland rail centre).

By contrast, 61.0 percent of illuminating oil produced in Baku in 1902 left by rail and hence would have been subject to immediate disruption from the railroad strikes. [Thompson, p. 14].

Figure presented by Henry appear to support these hypotheses. He reports that shipments of petroleum products from Baku by sea in the first six months of 1905 totalled 190.9 million poods or just about half the full-year total for 1904. By contrast, shipments by rail for the first six months of 1905 were only about 30 percent of the full 1904 figure.

Given the preponderance of *astatki* in the sea trade and illuminating oil in the rail trade [Thompson, p. 14], it seems reasonable to conclude that illuminating oil markets must have been more greatly disturbed than were *astatki* markets, at least in the initial post-Baku phase of distribution. Although it is a personal value judgement, this writer is inclined to believe that Russia was better off with this mix of shortages than with relatively more kerosene and relatively less *astatki*.

Another important feature of the distribution system in the crisis was the adaptation of marketing to extreme seasonality.

In 1902 about 75 percent of all Baku petroleum products were sent up the Volga River. [Thompson, p. 14]. But since this waterway froze in October and remained unnavigable for about six months, it was necessary to move most of the oil products to be consumed in the interior of Russia during the six month thaw.

The seasonal nature of distribution had important implications when the disturbances came. The Baku strike of December 1904 reduced crude oil production in Baku by about 60 percent, but must have had little effect on the Volga markets since it came well after the navigation season had ended. [Henry, p. 250; U. S. DI (1905), p. 897]. In like manner, the Baku pogroms in February should have had little effect on the Volga markets since they occurred before the opening of the new shipping season. Finally, restocking of the interior must have been well along before new violence broke in September. According to Henry (p. 245), the amount of oil products shipped up the Volga in the first eight months of 1905 was only about 10 percent behind the eight-month total for 1904.

Had major violence come in April, May, or June when inventories in the interior were low the disruption of the Russian economy would probably have been much more severe.

Finally, the shortages of petroleum products during 1905 were reduced to some extent by the general strikes which marked that year. To the extent that factories and railroads were shut down by these general strikes this should have reduced the *demand* for petroleum products, especially *astatki*. This decrease in demand should have relieved some of the upward pressure on prices resulting from reductions in supplies.

Inventories as a Buffer

Industry statistics make it clear that a substantial part of the potential blow to petroleum users in 1905 was absorbed by inventories.

We have a rather imprecise picture of the location and capacity of petroleum storage facilities, but it is clear that such facilities were widespread and must have had a substantial combined capacity. Baku itself had stocks which totaled more than 166 millions poods on January 1, 1902, and, as will be shown below, Batoum must have had storage space for at least 15 million poods on the eve of the revolution. Other important distribution points included Novorossisk with over 5 millions poods of storage capacity and Tsaritsyn with storage for about 11.6 million poods. If the transportation system is also viewed as part of the storage system then the Caspian tanker fleet should be added in with its 1902 capacity of 12.0 million poods, about half of which we may assume at any given time was loaded and moving north toward Astrakhan. To this must be added an unknown capacity of railroad tank cars, pipelines, and regional storage facilities. [Henry, p. 252; U. S. DI (1905), p. 900; Thompson, pp. 27, 29].

The buffer role of Baku inventories can be surmised from several simple statistics: from 1904 to 1905 production of crude oil in the Baku fields fell by 32.5 percent, but total shipments from Baku fell by only 24.5 percent. [Calc. from U. S. DI (1906), p. 890].

The clearest evidence of the buffer role of inventories is given by statistics on Batoum. According to Ingalls [(1905), p. 478] Batoum was able during 1905 to ship over 12 million more poods of petroleum products than it received from Baku during the year. Allowing for consumption in Batoum itself and inventories which at the end of 1905 stood at 3,584,000 poods, it is evident that Batoum's inventories at the beginning of 1905 must have exceeded 15 million poods. [U. S. DI (1905), p. 900].

A more modest buffer phenomenon is revealed by statistics on Novorossisk: during 1905 shipments out of Novorossisk totaled 12,279,000 poods or 687,000 poods more than arrivals (11,592,000 poods). As a result, stocks of petroleum products at Novorossisk fell from 5,217,000 poods on January 1, 1905, to 2,263,000 poods on January 1, 1906.[8] [U. S. DI (1905), p. 900].

Finally, there is the unknown, but obviously substantial role of inventories in the interior of Russia. As noted earlier, about 75 percent of all petroleum products shipped from Baku moved to the interior via the Caspian Sea — Volga River route. But since this water way froze for about six months each year it was necessary to have aggregate storage capacity in the interior for roughly half a year's consumption.

Of course the size of these interior stocks and hence the degree of independence from Baku must have varied seasonally. At the close of the navigation season storage facilities must have been full to bursting, while by April they must have been down to the seasonal lows. As noted in the last section, the strike in December 1904 and the massacres in February 1905 should have had little immediate effect on the Volga region since the navigation season had already ended, while restocking of the interior should have been well along before the September violence broke in Baku. It therefore seems likely that inventories in the Volga region were substantial during the critical periods of 1905 and must have helped to reduce the disruption to industry and transportation which attended the crisis.

As a final point on inventories, it was reported in October of 1905 that the Ministry of Ways and Communications had made 4 million poods of fuel (evidently *astatki*) available to Volga navigation companies out of its stocks. [U. S. DCL No. 301, p. 156].

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[8] The units of measure for these statistics are not given, but evidence in Henry (p. 221) indicates that they are measured in poods. The change in inventories exceeds the excess of shipments over arrivals because of consumption within Novorossisk itself.

A matching of data from two sources suggests that during the first half of 1905 shipments from Novorossisk were only 29.6 percent below the comparable period in 1904, but were 74.6 percent behind during the second half. [Henry, p. 211; U.S. DI (1905), p. 900].

Exports as a Buffer

There is some evidence that exports acted as a buffer in 1905, serving to partially shield the domestic market. Production of crude oil fell by 30.5 percent from 1904 to 1905. [Kelly and Kano, Table 4]. By comparison, exports from Batoum, the chief centre for exports of Russian petroleum products, fell by 42.9 percent (during the first nine months of 1905). [Henry, p. 254].

In large part this was probably caused by a general reduction of shipments from Baku to Batoum and from Batoum to all other points. But as data in Henry (p. 254) make clear, the buffer phenomenon also showed up in the form of modest increases in the *share* of Batoum shipments bound for other points in the Russian Empire.

The export buffer phenomenon can also be found in data on Novorossisk: shipments to Russia fell by 38 percent (from 2.6 million poods in 1904 to 1.6 million in 1905), while shipments abroad fell by 56 percent (from 24.4 million in 1904 to 10.7 million in 1905). [U. S. DI (1905), p. 900].

Only in the case of Persia, one of the smaller export markets, was the pattern reversed: exports to that country from the Baku region actually increased by 14 percent from 1904 to 1905 (from 1.4 million to 1.6 million poods). [Russia (1915), pp. 524-25].

There are several possible explanations for the emergence of exports as a buffer. One can be couched in terms of availability of alternative transportation modes. Batoum and Novorossisk were both dependent on the railroads for receipt of shipments from producing centre (Baku and Groznyy). Since the railroads were greatly affected by the 1905 Revolution it is possible that much of the shortchanging of the foreign market was due to the disruption of the railroads. The modest decline in the share of shipments leaving Batoum for non-Russian markets and the increase in shipments to Persia (presumably by ship) would fit well with this transportation hypothesis.

Alternatively, one could stress the relative profitability of alternative markets. Prices of petroleum products (at Baku) rose substantially after May 1, more than doubling by the end of September; by contrast, prices in New York, London, Liverpool, Antwerp, and Bremen were relatively stable. [U. S. DI (1905), pp. 885, 886, and 901]. This suggests that a profit-maximizing Russian producer would find it more advantageous to ship to domestic customers rather than abroad.

Finally, it is possible that preference was given to domestic markets for other reasons, e.g., patriotic motives. At the moment, we can see little way to distinguish between these three hypotheses as explanations of the observed phenomenon. With more study, however, it may eventually be possible to reach a judgement about their relative merits.

The Role of Groznyy and Fergana in 1905

After the four old Baku fields (Balakhany, Sabunchi, Romany, and Bibi-Eybat) the largest oil field in the Russian Empire in 1905 was at Groznyy, about 400 miles northwest of Baku. According to Henry, Groznyy was " well clear of the insurrection zone " and hence should have been able to keep supplying petroleum, unless the railroad strikes or general work stoppages interfered with it. [Henry, p. 248].

This is borne out by the statistics. According to Kelly and Kano, production of crude oil at Groznyy in 1905 reached a record 43.1 million poods, about 7.5 percent ahead of the 1904 level of 40.1 million poods. [Kelly and Kano, Table 8a].

Unfortunately, we are less sure of the actual impact of the Groznyy field on Russian markets because of limited information on shipments. We do know that Groznyy was linked via the Vladikavkaz Railway with Petrovsk to the east (on the Caspian), Novorossisk to the west (on the Black Sea) and other cities such as Rostov, and that the Vladikavkaz Railway joined the national strike late in October. [Westwood, pp. 100, 168, 302-3; Trotsky, p. 92]. But our only direct evidence does not suggest that Groznyy did much to relieve the crisis: 1905 shipments from Groznyy to Novorossisk were off by 55.8 percent (3.8 million poods vs. 8.6 million in 1904). [U. S. DI (1905), p. 900]. This is not conclusive evidence, however. Novorossisk was primarily a transshipment point for products going abroad (90 percent of shipments from Novorossisk in 1904). Given the great increase in domestic petroleum prices in 1905 it seems likely that producers would have supplied the Russian market in preference to foreign markets. If so, products from Groznyy would probably have gone further north on the Vladikavkaz Railway, bypassing Novorossisk, or would have gone east to Petrovsk for shipment to the interior via the Volga.

In the only other field worth mentioning — Fergana — production rose from 0.5 million poods in 1904 to 2.1 million poods in 1905. [Kelly and Kano, Table 8c]. Unfortunately we have no information on shipments from Fergana.

Combining the data on Groznyy and Fergana we find that crude oil production at these two fields rose by a total of 4.6 million poods. If this extra output did reach the Russian market in 1905 it would have made up for only 2.3 percent of the 203.9 million pood decline in production at the four old Baku fields from 1904 to 1905. [Kelly and Kano, Table 4].

Summary

It is evident that the 1905 oil crisis was met in a number of ways. The producers and users of petroleum were aided by fortuitous circumstances, including the timing of the disturbances (at noncritical times) and by the fact that the key artery of the distribution network — the Caspian Sea-Volga River water route — was not seriously disrupted.

Second in importance in meeting the crisis was the network of storage facilities around the country, which played an important buffer role. By drawing down stocks in Baku itself it was possible to trim a 32.5 percent decline in production to only a 24.5 percent decline in shipments. Batoum, Novorossisk, and numerous interior distribution points must have contributed in a similar fashion.

The shortages for the domestic market also appear to have been eased by disproportionate reductions in exports, by increases in production outside of Baku (e.g., Groznyy and Fergana), and by reductions in demand resulting from strikes at facilities using petroleum products, especially astatki.

Finally, it is likely that increases in prices for petroleum products during 1905 led to reductions in the quantity of these products demanded.

IV

Short-Term Responses (1905-1907)

Movements in Revenue

Recovery began immediately. Monthly production of crude, which had fallen from 32.3 million poods in August 1905 to 2.2 million poods in September, bounced back to 18.4 million in October. [U. S. DI (1905), p. 897].

However, this initial phase of recovery probably reflects the resumption of production by undamaged wells. Revitalization of damaged wells was a slower and much more expensive proposition.

Reconstruction of the industry was aided by healthy trends in revenues, as can be seen from Table 3. Given the well-known price inelasticity of demand for petroleum, it should not surprise the reader that declines in supplies were accompanied by price increases sufficient to counter much of the detrimental effect of output declines on revenues. Output at the four old Baku fields declined by 33 percent from 1904 to 1905, but prices rose by an equal percentage, leaving 1905 "crude oil revenues" only 11 percent below the 1904 level.[9] Simultaneous advances of both price and output in 1906 and 1907 boosted crude oil revenues well above the 1904 level, as can be seen from Table 3.

TABLE 3

PRICES, OUTPUT, AND CRUDE OIL REVENUES
IN THE FOUR OLD BAKU FIELDS, 1903-1907

Year	Price [a]	Output [b]	Crude Oil Revenue [c]
1903	8.9	596.3	53.1
1904	14.4	613.3	88.3
1905	19.2	409.4	78.6
1906	25.6	447.7	114.6
1907	27.4	476.0	130.4

a) Price of crude oil at Baku in copecks per pood. Taken from appendix table.
b) Production of crude oil at Balakhany, Sabunchi, Romany, and Bibi-Eybat, in millions of poods. From Kelly and Kano, Table 4.
c) Column a × column b/100. In millions of roubles.

It is interesting to compare the increases in revenue in 1906 over 1904 with the estimates of damage in Table 1. Crude oil revenues in 1906 equaled 114.6 million roubles or 26.3 million roubles more than in 1904. Using the exchange rate given in Thompson (p. 397) of 9.45 roubles = £ 1 sterling makes this increase in revenue equal to about £ 2.8 million, or more than enough to cover estimated costs of damage, even if the producers' figures are used. (See Table 1.) Increases in 1907 were even

[9] Several comments are needed on Table 3. FIRST, "crude oil revenues" is an artificial construct derived from the product of estimates of prices and output, and hence is only an approximation of actual revenues at that stage of production. Second, one cannot easily estimate the elasticity of demand for crude oil from Table 3 because other things did not remain equal over the period covered and because each price is an average of widely divergent prices during subperiods of the year.

greater. Of course, the capacity of individual producers to pay for their damages out of extra revenues would depend on their shares in the destruction and higher revenues and on current operating costs and the cost of replacement equipment. As noted below, the price of one form of replacement equipment — derricks — rose sharply after the destruction.

The Process of Recovery

The decline and recovery of the four old Baku fields can be better understood from Table 4, in spite of evident anomalies in the data contained in the table.

Comparing the situation at the end of 1905 and 1904, one can see that the number of producing wells fell by over 43 percent, from 1555 to 880, while the number of wells standing idle rose by 68 percent, from 1443 to 2423. In addition, categories of wells which could be expected to move into production in the future (trial pumping, drilling, cleaning out and repairing, etc.) all showed marked declines. But if these data can be matched with those presented by Henry, the industry had already made substantial progress by the end of 1905, having increased the number of producing wells from 583 remaining after the September fires to 880. [Henry, p. 215].

The oil well statistics for 1906 seem to show a spectacular recovery. Wells standing idle fell from 2423 to 1799, all pre-production categories showed spectacular increases (e.g., wells in the trial pumping stage rose from 14 to 627), and, most important, the number of producing wells almost tripled, rising from 890 to 2613.

But for all this statistical movement, 1906 was not a good year. Production of crude by the four old Baku fields did expand, rising from 409.4 million poods in 1905 to 447.7 million in 1906, but came nowhere near the 1904 total of 613.3 million poods. [Kelly and Kano, Table 4].

TABLE 4

NUMBER AND CONDITION OF OIL WELLS IN THE BAKU FIELDS
AS OF DECEMBER 31

Conditions of Wells	1904	1905	1906
Completed	239	154	176
Producing	1555	880 [a]	2613 [a]
Trial pumping	31	14	627
Drilling	279	141	711
Drilling deeper	66	91	209
Cleaning out and repairing	327	46	677
Standing idle	1443	2423 [b]	1799
Rigs up, ready for drilling	60	53	196
New wells sunk	312	140	249
Length drilled (sazhenes)	62,248	35,663	48,104

a) Includes 12 wells in Binagadi.
b) Includes 7 wells in Binagadi.
one sazhene = 7 feet.

Sources: U.S. DI (1905), p. 898. U.S. DI (1906), p. 891.

It seems evident that many of the additional wells brought into production must have been low yield strippers. In particular, the tremendous surge in the total number of wells accounted for in the 1906 statistics in comparison with 1905 or 1904, suggests that many wells must have moved from the abandoned category (not shown in the table) to the various categories shown, including " producing ". The higher crude prices would, of course, encourage such efforts.

Reports by contemporaries on the recover process show wild swings between optimism and pessimism. As noted in Part II, the first damage estimates were quite alarming. But by the time Henry was finishing his book in November of 1905 he was relatively optimistic:

> Reports which are daily reaching London state that the work of re-building the derricks, cleaning out the wells and erecting drilling and pumping machinery is being pushed on with all possible speed. [Henry, p. 246].

A report on 1905 in Ingalls was still more buoyant, even seeing long run gains from the destruction of obsolete equipment. A year later, the same source was much more pessimistic: " All these circumstances prove that the time is still far distant when the Baku naphtha production will resume its former standing." [Ingalls (1905), p. 477; Ingalls (1906), p. 618].

Recovery was impeded by a number of circumstances. In spite of a sharp rise in the price of derricks, it proved impossible to replace more than half of those destroyed in the fires by the end of 1906. A more serious long-term problem was the increasing intrusion of water into the wells. Henry reports that on the average two poods of water were being bailed out for every pood of oil and some wells were facing ratios of 4:1 or even 8:1. The interruption of production aggravated this problem.[10] Finally, there was a continuation of labour problems, including strikes, extortion, and even murder. [Henry, p. 246; Ingalls (1906), p. 618; Thompson, p. 37; Ingalls (1907), p. 767].

As will be seen in the next section, a pattern of relative stagnation followed this period of weak and rather uncertain recovery.

V

Long Run Responses (1905-1913)

The purpose of this section is to trace some long-run results of the violence in 1905 through an examination of trends in crude oil prices and trends in the use of one major petroleum product (astatki), and through scenario analysis bases on a model of the industry. The discussion relies heavily on time series data and hence is subject to the well-known limitations associated with that type of information.

[10] It is interesting to note that the C.I.A. considers water intrusion to be one of the major problems of the Soviet oil industry today. [U.S. CIA, pp. 6-7].

Price Trends

From the appendix it can be seen that prices of crude oil, as quoted in Baku, rose after 1904. In fact, prices averaged 25.4 copecks per pood during the period 1905-13, or 147 percent above the average for the preceding nine years (1896-1904): 10.3 copecks per pood.

It is evident that some increases should have been expected: wells were becoming deeper, the most accessible and most easily tapped deposits were gradually being depleted, and new drilling was at a lower level than one would have predicted. In addition, the labour difficulties which continued to plague the industry must have also pushed costs higher.

These higher prices had a number of consequences for the producers and users of petroleum products, as will be shown below.

Loss of Markets

One result of the increased price of crude oil after 1904 was the loss of some domestic markets to competing fuels. We are not in a position to paint a complete picture of this process, but will present two examples which seem indicative of domestic trends — the use of *astatki* by railroads and shippers on the inland waterways.

At the turn of the century there were three main competing fuels in the Russian Empire: wood, coal, and *astatki*. The location of production sites for each fuel, the cost of producing the fuel, and transportation costs naturally defined regions in which each fuel was supreme. Coal was produced largely in the Donets Basin in the southwest, petroleum in Baku and Groznyy in the Caspian Region, and wood in the northern and eastern regions. But regional boundaries for fuels shifted as production and transportation costs changed.

Beginning in the late 1870's or early 1880's, *astatki* began to be used on some of the railroads. According to Crawford

116,000 poods of *astatki* were consumed by the railroads in 1881. By 1888 the total had expanded 75 fold, reaching 8.7 million poods or 7.9 percent of all fuel consumed by the railroads. Astatki use continued to expand until 1900 when it totaled 104 million poods or 34.4 percent of total fuel use on the railroads (vs. 41.8 percent for coal and 23.8 percent for wood).[11] [Crawford, II, p. 508; Knorre, pp. 723-24].

The turn of the century seems to have marked a peak in railroad usage of *astatki*, in percentage terms. The slide was gradual at first, falling to 30.7 percent in 1905 and 29.6 percent in 1910. But from there it fell much more sharply, dropping to 21.7 percent of all fuels in 1913. In absolute terms, consumption of *astatki* by the railroads continued to rise until 1904, reaching 130 million poods, but then fell sharply to 111 million in 1906; from there it fell more slowly to 109 million poods in 1913. [Knorre, pp. 723-24].

Similar trends developed in shipping on the interior waterways. Consumption of *astatki* by such shippers expanded from 17.1 million poods in 1886 to 35.1 million in 1890 and 67 million in 1900. But from that level consumption fell to 50 million poods in 1910 and 40 million in 1913. In the process, the share of *astatki* in the total inland waterway market fell from 27.9 percent (1900) to 20.0 percent (1913). [Crawford, II, p. 511; Knorre, p. 725].

Although the data are incomplete, the explanation for these trends seems reasonably clear. Data presented in Table 5 suggests a steady and perhaps slightly falling price for coal from 1905

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11 KNORRE (p. 724) does not explain the basis for the percentage figures he reports, but conversion of raw figures on consumption of wood, coal, and oil which he reports elsewhere (p. 723) into a common energy basis (cubic sazhenes of wood), using conversion figures in Crawford (II, p. 508), yields percentage figures similar to those reported by KNORRE (p. 724). Hence, the percentage figures appear to be based on heating power of the fuels; Crawford suggests as representative conversion figures: one cubic *sazhene* of wood = 71 poods of *astatki* = 108 poods of smoked Donets coal. One *sazhene* equals seven feet. [Thompson, p. 397].

TABLE 5

MOVEMENT OF RELATIVE PRICES OF COAL AND CRUDE OIL

(1) Year	(2) Coal [b]	(3) Crude Oil [c]	(4) (3) / (2)	(5) Relative Price Index [a]
1905	32.0	19.2	.60	100
1908	32.0	21.7	.68	113
1911	30.8	22.1	.72	120

a) Column (4) / .60 × 100

Sources:
b) Copecks per pood. Taken from Knorre, p. 724.
c) Copecks per pood. Taken from Appendix.

to 1911. By contrast, the price of crude oil increased by 15 percent from 1905 to 1911. As can be seen from the last column of Table 5 these figures translate into a 20 percent increase in the price of crude oil *relative* to the price of coal. Since crude oil prices rose by 192 percent over the slightly longer period 1904 to 1913 it is likely that Table 5 understates the swing in relative prices. The existence of a stronger trend is supported by Westwood who writes that, " between 1895 and 1904 coal prices increased by a half while oil prices doubled ". [Westwood, p. 135].

Given the preponderance of steam technology on the railroads at this time, conversion from one fuel to another was technically possible and, according to Westwood, was a common response to changes in the relative prices of coal, oil, and wood. [Westwood, p. 13].

In summary, it would appear that the price of *astatki* rose relative to the price of coal after 1904 and that as a result, the share of the transportation market going to *astatki* declined. Similar trends probably also prevailed in consumption of fuels by industrial plants along the Volga and in the Moscow region.

These conclusions must be tentative in the absence of more information. An obvious potential difficulty is the problem of

4

changes in the regional demand for transportation services. If the demand for transportation were to expand more rapidly in the region served by coal than in the region served by petroleum this could lead to a shrinking share for petroleum. Although such differential regional growth would not explain the absolute declines in *astatki* consumption recorded for the railroads and inland shipping, it is clear that the regional growth factor should be investigated. There is also more scope for investigation of trends in intercity price differentials and freight charges and their roles in shifting the boundaries of various fuel regions.[12]

A Model of the Industry

In trying to assess the longer run consequences of the 1905 violence we are compelled to compare actual history with the hypothetical history which might have unfolded in the absence of the violence. This is not an unreasonable task if one does not carry it to extremes, but it does require a reasoned view of what the alternative course of events might have been. One cannot simply assume that 1904 would have repeated itself each year until World War I began. One can, however, seek to discover the separate underlying relationships and trends characterizing the industry and see what would have happened if these relationships and trends had continued. The purpose of this section is to present a simplified model of the industry before 1905, to use this model to project output and other characteristics of the industry up through 1913, and to compare the scenario suggested by the model with what actually happened.[13] The model is

[12] In commenting on Metzer's market integration work, Kelly (1976) has provided some evidence of intercity price differentials for astatki. However, little or nothing has been done on price differentials for coal or wood.

[13] The model presented here lacks the theoretical precision of Davidson's model, but is adapted to the available data and hence can be used for projection purposes. By contrast, Davidson's discussion is limited to a theoretical exposition and does not venture into the realms of estimation and projection. In formulating this model the author has

limited to the four old Baku fields where most of the violence occurred.

It is well known that an oil deposit will not produce forever and will gradually become depleted as oil is extracted. As a result, producers must find new deposits and drill new wells or face the prospect of declining production. The model is predicated on this simple fact.

Ideally one would define a depletion model in terms of a combination of measures of oil deposits and wells tapping them. But since the dimensions of oil deposits are known only imperfectly this model is defined in terms of measures of wells.

Specifically, we define a theoretical measure of ability to produce oil which we call the "adjusted stock of past drilling". Ability to produce oil is hypothesized to be a function of the cumulative amount of drilling which has been carried out in the past, adjusted for the debilitation and "death" of old wells. The process of calculating the adjusted stock of drilling available in year t ($D_t^{\Sigma A}$) can be summarized as:

$$D_t^{\Sigma A} = \alpha D_t^n + \beta D_{t-1}^{\Sigma A} \qquad (1)$$

where

D_t^n is the amount of new drilling in year t and

α and β are "exhaustion" factors, indicating the percent of productive ability retained after various periods for new and past drilling, respectively. The first (α) indicates the percent of effective productive ability which is retained by new drilling during the first year, while β indicates the retention of productive ability of past drilling in any subsequent year (second, third, etc.), as a percentage of productive ability in the previous year (first, second, etc.). The last term ($D_{t-1}^{\Sigma A}$) is the adjusted stock of drilling available during the previous year (t-1), calculated by the same formula.

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benefited from numerous discussions with one of his graduate students, Mr. Gerald J. Fico, Jr.

The reasoning is as follows. At any given point in time there exists a past stock of drilling which is gradually being "exhausted" as depletion of oil deposits takes place. However, the decline in the effective stock of past drilling is being countered to some extent by new drilling.

The exhaustion factors α and β were estimated from data in Henry. These data showed the average yield per new well during the year in which it was drilled, for wells drilled from 1888 through 1903, as well as the average yield for each cohort of wells for subsequent years through 1903. From these figures it was possible to calculate average yields in later years as a percentage of the first year's yield for that cohort of wells. [Henry, p. 138].

The observations thus obtained were used to estimate α and β via linear regression, using a logarithmic (and hence linear) form of the common decay function

$$C = \alpha e^{-rt} \tag{2}$$

where in this case

C is the yield in year t as a percentage of the first year yield;

e^{-r} is equal to β (defined above);

e is the natural logarithm base; and

α and t are as defined above.[14]

The annual loss of yield in percentage terms will be $(1-\alpha)$ during the first year and $(1-\beta)$ between subsequent pairs of years.

[14] For other applications of the decay function see Kelly (1971). The careful reader may wonder how α can be anything but 1.0 since our first-year observations calculated from Henry all equal 1.0, by definition. We could have constrained α to be 1.0 in the regressions, but would have obtained an estimated relationship with lower predictive ability if we had. The problem (as usual) is that the real world is more complex than our simple decay model suggests. Henry (p. 139) indicates that production from a well declines most rapidly (in percentage terms) during the initial years of well life, while our constant β implies a constant rate of decline after the first year. Estimation of two separate exhaustion factors (α and β) provides partial compensation for this situation.

Using the sample of 133 observations generated from Henry, the following relationship was estimated:

$$\text{In } C = \underset{(0.058)}{6.758} - \underset{(0.009)}{0.179}\, t \quad \frac{R^{-2}}{.746} \qquad (3)$$

where the standard error of the regression coefficient is shown in parentheses. The relationship is highly significant as evidenced by the t-score of 19.7. Converting this equation to antilog form results in the decay function:

$$C = 0.861\ e^{-0.179t} \qquad (4)$$

which yields values for α and β of 0.861 and 0.836, respectively.

After substituting these values into equation (1), it was possible to calculate a time series for the adjusted stock of drilling. The movement of this variable from 1885 to 1913 is shown in Figure 1.

The balance of the predictive model follows from the assumption that actual output depends on the current adjusted stock of drilling and the "productivity" of that stock of drilling (P_t). The model is derived from an identity about actual current output of crude oil (O_t^a):

$$O_t^a \equiv O_t^a \qquad (5)$$

$$O_t^a \equiv \frac{O_t^a}{D_t^{\Sigma A}} \cdot D_t^{\Sigma A} \qquad (6)$$

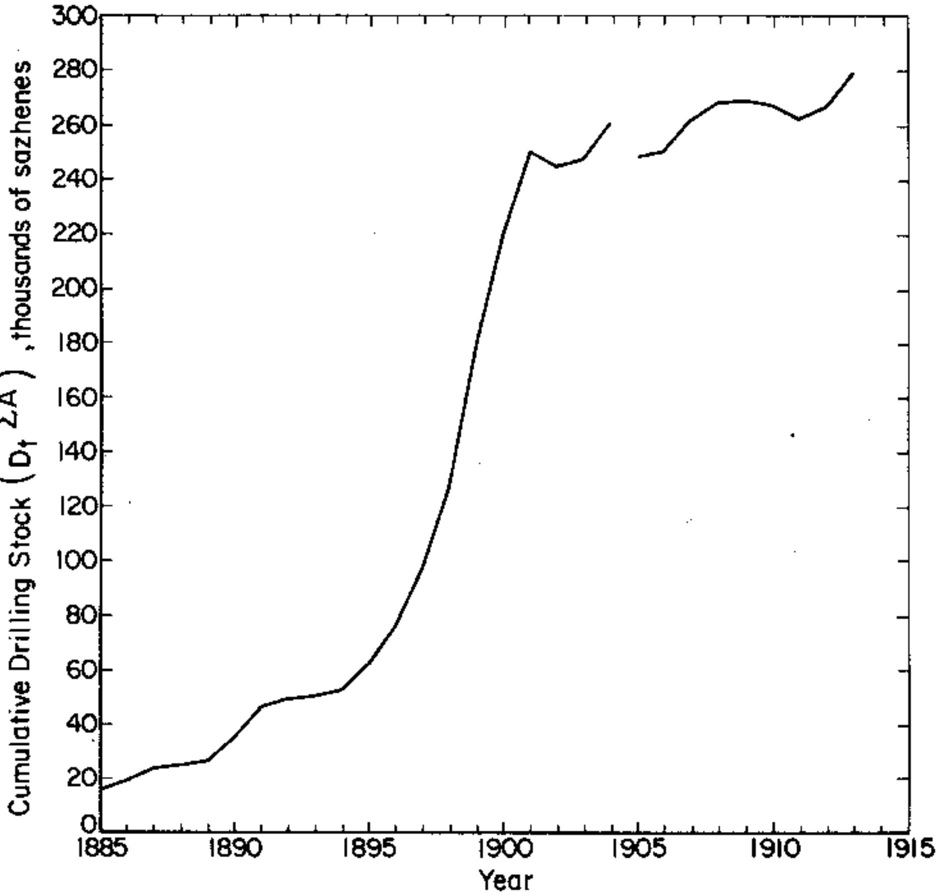
$$O_t^a \equiv P_t \cdot D_t^{\Sigma A} \qquad (7)$$

where

$$P_t \equiv \frac{O_t^a}{D_t^{\Sigma A}} \qquad (8)$$

As a statement of past activities equation (7) is not of much interest, because it is an identity. But if one could make independent predictions of P_t and $D_t^{\Sigma A}$ into the future, then equation (7) could offer a way of predicting future output, albeit in a crude way.

Figure 1



Cumulative Drilling Stock $(D_t \Sigma A)$, thousands of sazhenes
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
1885
1890
1895
1900
1905
1910
1915
Year

Use of equation (7) as a predictive model requires separate models for $D_t^{\Sigma A}$ and P_t. From equation (1) and subsequent discussion it can be seen that $D_t^{\Sigma A}$ can be projected into the future in an iterative fashion if only one can develop a theory of new drilling.

A simple version of such a theory is that new drilling in a particular year is a positive function of prices in the previous year. Regression of drilling in the four old Baku fields (measured in thousands of sazhenes) on crude oil price in the previous year (Π_{t-1}) for the drilling years 1891-1904 yielded the following relationship:

$$D_t^n = \underset{(6.871)}{3.136} + \underset{(0.827)}{5.423}\, \Pi_{t-1} \qquad \frac{\bar{R}^2}{.763} \tag{9}$$

where the standard error of the regression coefficient is again shown in parentheses.[15] The regression coefficient is highly significant as shown by the t-score of 6.6.

Let us now turn to the prediction of productivity. It seems reasonable to relate productivity (P_t) to depletion, to the extent that depletion has not been fully represented in the model. Of course, $D_t^{\Sigma A}$ incorporates one form of depletion — the reduction of yield of individual wells or cohorts of wells over time as the oil deposits they tap are emptied and gas pressure is lost. But there is a second type of depletion not yet considered. To the extent that producers can distinguish rich oil deposits from poorer or less accessible ones we would expect them to tap the former first and delay using the latter until the richest deposits are exhausted.

If this phenomenon can be captured by our productivity

[15] The drilling observations for 1892 and 1893 are from U.S. Dept. of the Interior, U. S. Geological Survey, *Mineral Resources of the United States*: 1893 (Washington, D.C.: U.S. Government Printing Office, 1894), p. 512, while those for 1896 and 1902 are from HENRY, p. 134. All other drilling observations are from PAZHITNOV, pp. 84, 137. Price data are from the appendix to this paper.

variable (P_t) then P_t should have a negative relationship to cumulative past production of crude oil ((ΣO_i^a)):

$$P_t = f(\sum_{i=1}^{t-1} O_i^a). \tag{10}$$

In pursuit of this hypothesis, a time series of P_t was calculated (see Figure 2) and exploratory regressions of P_t against cumulative output in the four old Baku fields were carried out for various subperiods of the period 1878-1913. The relationship proved to be significant, but of a complex nonlinear nature. For purposes of understanding developments after 1904 we settled on a simple linear regression for the years 1899-1904, 1909-1913 which yielded the equation: [16]

$$P_t = \underset{(0.050)}{3.763} - \underset{(0.006)}{0.198} \sum_{1}^{t-1} O_i \qquad \frac{\bar{R}^2}{.991} \tag{11}$$

The dependent variable, P_t, is measured in thousands of poods per sazhene of adjusted past drilling and ΣO is measured in billions of poods. Like the previous regression coefficients, this one is highly significant, having a t-score of 33.3.

We now have the basis for an iterative model for prediction

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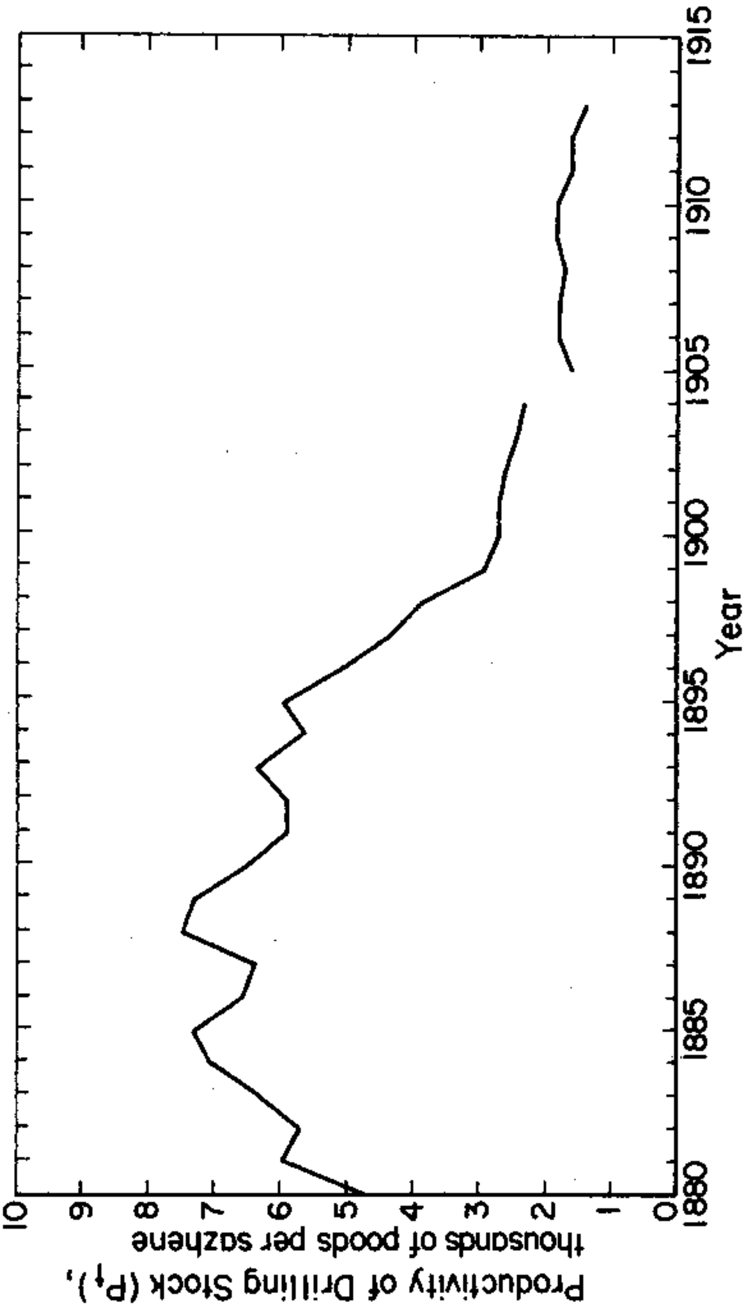
[16] In order to avoid fitting a complex nonlinear regression to the entire period with no clear theoretical preference for any particular form, it was decided to examine a shorter period. Observations for the years 1899-1913 seemed to show a steady linear relationship between P_t and $\Sigma 0$ from 1899 to 1904, a sharp deviation from this relationship in 1905, and a gradual return to the old relationship as P_t recovered. We therefore fit a linear regression to the six years 1899-1904 and projected values of P_t into the future using the actual values of $\Sigma 0$. Comparing projected and actual values of P_t it appeared that by 1909 the actual value of P_t was back on trend. The years 1909-1913 were then added to the previous sample (1899-1904) and the relationship was re-estimated. The resulting equation, shown in the text, was almost identical to that for the years 1899-1904, suggesting that the later observations were generated by the same process.

Finally, time was tried as an alternate predictor of P_t. This yielded results which were slightly better than those obtained using $\Sigma 0$. We were suitably humbled by these results, but have not used them since we regard time as a proxy for $\Sigma 0$.

Figure 2


Productivity of Drilling Stock (P_t),
thousands of poods per sazhene
0
1
2
3
4
5
6
7
8
9
10
Year
1880
1885
1890
1895
1900
1905
1910
1915

of future output. The model is not as complete as we might like since we do not have an explicit model of prices. In the absence of a price model we have followed two alternative assumptions with respect to prices. In Scenario I it has been assumed that the average crude oil price for the preceding five years (1900-1904) — 10.8 copecks per pood — continued through the projection period (1905-1913). In Scenario II it was assumed that crude oil prices would continue to rise through the projection period in accordance with a time trend estimated by linear regression for the period 1890-1904.

The projection process operated as follows. Given the assumed price for crude oil we were able to calculate new drilling (D_t^n) from equation (9) above and, by an iterative process using equations (1) - (4), to in turn calculate $D_t^{\Sigma A}$ for each future year. Beginning with actual cumulative output in 1904 it was then possible to project P^t for 1905 from equation (11) and, with $D_t^{\Sigma A}$, to project output in 1905 via equation (7). With output in 1905 plus cumulative output through 1904 it was possible to calculate $\Sigma 0$ through 1905 and hence P_t for 1906. Calculations proceeded in this iterative fashion for subsequent years.

The results, in terms of output, can be seen from the upper panel of Figure 3, where the lower line shows actual output from 1900 to 1913 and the upper lines show projected output from 1904 to 1913.

According to Scenario I, output would have fallen from 1904 to 1905, but by only 3.1 percent rather than the actual decline of 33.2 percent. For the entire 1905-13 period, our projection indicates that output would have shown a continuous decline, leaving 1913 output about 31 percent below the 1904 level (vs. an actual output decline of 36 percent). Although production would have declined in any case according to Scenario I, the loss of output was still substantial, amounting to 635 million poods or about 13.7 percent of total projected output over the period. This loss was the equivalent of an entire year of production by the four fields at the rates which prevailed shortly after the turn of the century. About 29 percent of this loss occurred in 1905 itself, another 21 percent occurred in 1906, and the remaining 50 percent was lost over the following seven years.

Scenario II portrays a more optimistic picture of what might have been after 1904 and hence a more pessimistic evaluation of the consequences of the 1905 Revolution. According to this scenario, 1905 output would have been 2.9 percent *above* that of 1904 (vs. an actual decline of 33.2 percent). And for the entire 1905–13 period output would have peaked in 1905 (at 631 million poods) and then have declined continuously to about 538 million poods in 1913, or about 12 percent below the 1904 level (vs. an actual decline of 36 percent). The cumulative loss of output is substantially greater according to Scenario II (1389 million poods vs. 635 million in Scenario I), and is spread more evenly over the period with only 16 percent occurring in 1905, 13 percent in 1906, and the remaining 71 percent over the following seven years. The cumulative output loss according to this scenario was the equivalent of about two years of production by the four fields at turn of the century rates.

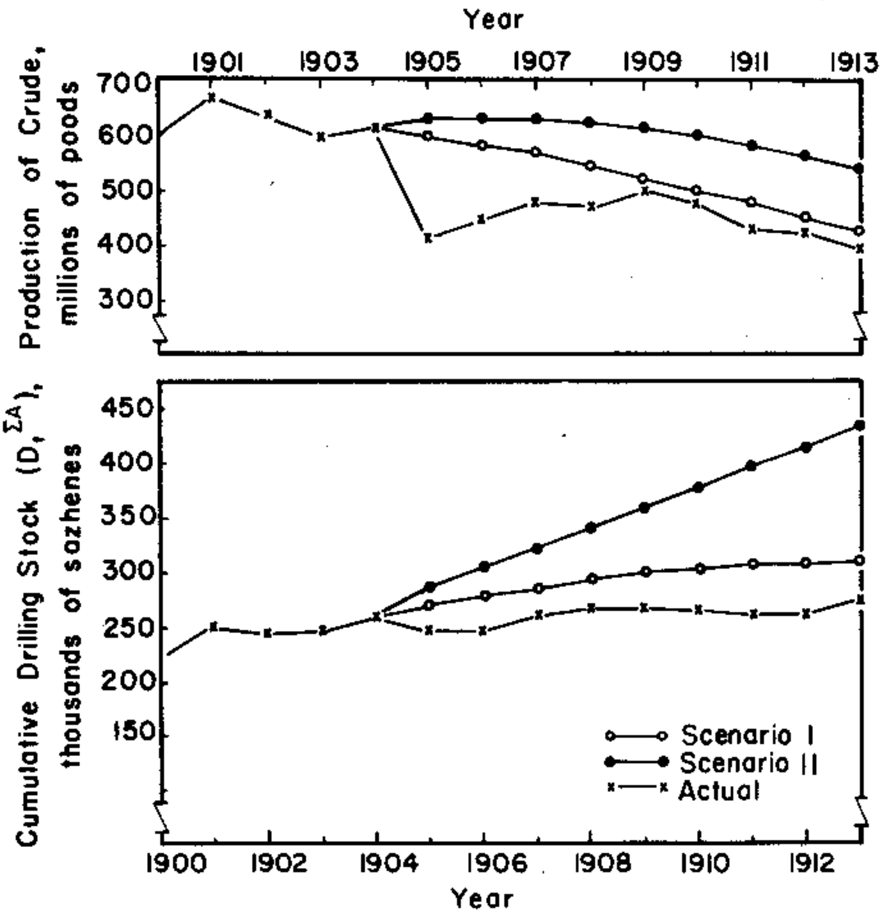
The next section examines the anatomy of the post 1904 period and the contribution of separate portions of the model to the observed results.

Analysis of the Post-1904 Period

Let us proceed by tracing the factors in the model in the order necessary for projection.

From the appendix table it can be seen that actual crude oil prices rose substantially after 1904, ranging from 15.1 to 42.0 copecks per pood. The average actual price during the 1905–13 period was 25.4 copecks per pood, well above the 10.8 copeck average under Scenario I and the 16.0 copeck price average under Scenario II.

Figure 3


Year
1901
1903
1905
1907
1909
1911
1913
Production of Crude, millions of poods
700
600
500
400
300
Cumulative Drilling Stock ($D_t^{\Sigma A}$), thousands of sazhenes
450
400
350
300
250
200
150
Scenario I
Scenario II
Actual
1900
1902
1904
1906
1908
1910
1912
Year

According to equation (9) the higher prices which materialized should have led to more drilling than assumed in either Scenario I or II. In fact, actual drilling was below projected drilling in every year except 1913 (Scenario I). For the entire period 1905–13, actual new drilling was off by about 16 percent in comparison with Scenario I and 41 percent in comparison with Scenario II. The effect on the adjusted stock of drilling can be judged from the lower panel of Figure 3.

To better understand these results we reestimated equation (9) using data for 1905-13.[17] The resulting equation was:

$$D_t^n = \underset{(4.573)}{22.291} + \underset{(0.198)}{1.318}\ \Pi_{t-1} \qquad \frac{\bar{R}^2}{.844} \qquad (12)$$

The regression coefficient is significant, having a t-score of 6.7.

Equation (12) is significantly different from equation (9) and gives lower predicted amounts of drilling for crude oil prices above 4.7 copecks per pood.[18] Comparing the regression coefficients of these two equations it becomes evident that drilling was much less responsive to price after 1904. As a result, although prices of crude oil were higher after 1904 than before, they were not high enough to induce an average level of drilling even equal to that which prevailed from 1900 to 1904.

Had new drilling taken place at the rates implied in our projections, the adjusted stock of drilling would have continued to grow (although at a declining percentage rate), until in 1913 it would have stood at a level 20 to 67 percent above that in 1904 (Scenarios I and II, respectively). In fact, $D_t^{\Sigma A}$ fell below the 1904 level in 1905 and 1906 and by 1913 was only 7 percent above the 1904 level.

[17] Drilling data are from PAZHITNOV, p. 137, while prices are from the appendix to this paper.

[18] A Chow test led to rejection, at the .01 level, of the hypothesis of equality of the coefficients of equations (9) and (12). [Johnston, pp. 136–38].

The decline and recovery of crude oil production was also influenced by changes in the productivity of the stock of past drilling (P_t) after 1904. In the absence of disturbing influences, equation (11) would lead us to expect a gradual decline in productivity as cumulative output increased over time. Instead, 1905 saw a sharp drop in productivity to a level about 25 percent below what would have prevailed in that year according to either of our scenarios. The gap narrowed gradually and closed during the 1908-1909 period. Interestingly enough, actual productivity from 1909 through 1913 was higher than projected by either scenario — because of lagging production. Within the context of our model it can be argued that the failure to drill as much as predicted after 1904 reduced the rate of depletion and left producers with higher quality fields in later years. As would be expected, Scenario II, which shows more buoyant output trends than Scenario I, is also marked by sharper declines in productivity.

Thus changes in the productivity of the stock of past drilling reinforced the depressing effects of deficits in new drilling through 1908, pulling actual output down even further. But from 1909 actual productivity was above projected levels, serving to partially offset the depressing effects of lags in new drilling.

To summarize, new drilling was needed each year if depletion effects were to be countered. But in the post-1904 period new drilling lagged, in spite of high prices which once would have induced a healthy amount of new drilling. While it is conjectural, it seems likely that the change in the relationship between price and drilling was due to a decline in the confidence of investors following the violence of 1905. Compounding this problem was a temporary tendency for the productivity of the past stock of drilling to fall below trend, perhaps because of the physical destruction in 1905 and continuing labour problems after 1904.

VI

Discussion and Conclusions

A number of tentative conclusions emerge. It is clear that the disruption to users of petroleum products resulting from the 1905 disturbances could have been much more serious if the disturbances had occurred at a different time of the year (when stocks in the interior were low) or if the Caspian Sea-Volga River artery had borne more of the brunt of the general strikes and violence. Russian industry was simply lucky.

Given the relatively short duration of the crisis, the distribution system seems to have absorbed much of the blow out of inventories located in Baku, Batoum, Novorossisk, and numerous points in the interior. Adaptation of the Russian economy to extreme seasonality left it well prepared to meet this particular crisis.[19] However, similar problems in the spring before the Volga opened would have brought much greater hardship.

Damage to producers was limited by certain characteristics of the oil industry. Investments in finding petroleum deposits are almost impervious to violent destruction, while underground facilities are relatively protected. The greatest destruction tends to fall upon surface facilities.

Given the inelastic demand for petroleum products, the reduction in supply which accompanied the disorders brought about a healthy flow of revenues to help finance reconstruction. While better estimates are needed, it seems that the increased revenues in 1906 and 1907 should have enabled the industry as a whole to make good its losses.

However, the recovery process did not proceed smoothly. Shortages of derricks, flooding of wells, and continuing labor

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[19] During the U.S. coal strike of 1977-78, electric power producers adapted to extreme seasonality in transportation, such as Detroit Edison, fared better than did many located in warmer areas.

unrest plagued the industry. As a result, production lagged and inventories could not be rebuilt rapidly. Productivity of past drilling suffered a sharp drop in 1905 and recovered slowly in the following years. But most serious for the long run picture was a reduced willingness to drill even when prices were high. As a result, by 1913 the adjusted stock of drilling was only 7 percent above the 1904 level (vs. a possible 20 to 67 percent increase by our alternative scenarios) and production lagged substantially during the 1905–1913 period.

Depletion seems to have been a fundamental reality which must determine any scenario of what might have been in the post-1904 period. Productivity of the stock of drilling was bound to decline (at least until new techniques such as water flooding were introduced). And unless new wells were drilled to replace the old ones, the stock of drilling was bound to decline also.

The scenarios presented above suggest that the long-run results of the 1905 Revolution should be measured as the gap between an ultimately falling trend (what might have been) and what was. Given our present state of knowledge about the industry it is difficult neatly to divide up that gap and assign portions of it to the various factors at work. The thrust of this paper has been to view the key factor — reduced willingness to drill — as a function of uncertainty brought on by continuing labor unrest.

An obvious alternative view of lagging production would focus on the cartel argument: production was held down by the cartels in order to raise prices and increase profits.[20] We are not comfortable with this alternative explanation. Obviously production did lag and prices did rise. However, given the way cartels typically operate it seems to us that a cartel would bring about a permanent lowering of our productivity variable (P_t).

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[20] Lyashchenko (p. 682) argues that in 1900 16 firms controlled about 65 percent of the Russian Empire's oil production and that cartelization increased over the following dozen years. By modern standards these figures would not be considered to represent an especially high concentration ratio.

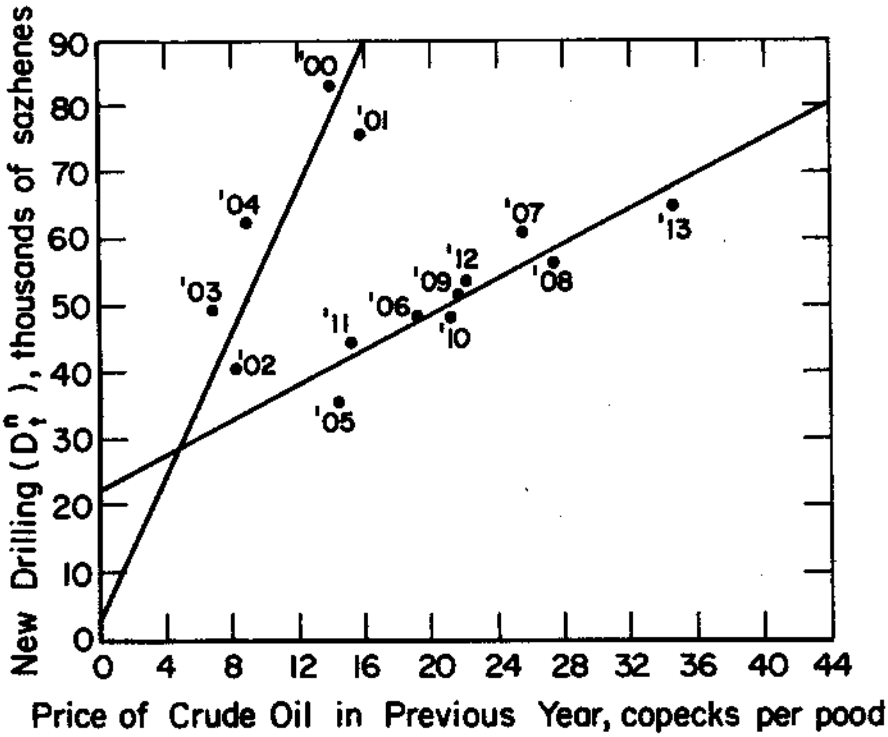
But as discussed in the text there does not seem to have been a permanent change in the relationship between P_t and cumulative output; P_t fell sharply from trend in 1905, but then gradually rose back until it regained the levels predicted by comulative output about 1910. This pattern seems to fit with a "crisis-recovery" view of developments rather than with a cartel view.

What did change sharply was the relationship between new drilling and the price of crude oil, as shown in equations (9) and (12). We would not expect a cartel to have direct control over drilling, but, of course, a strong cartel might have some indirect control: why drill additional wells if the cartel will not allow you to sell additional output? But such a hypothesis would seem to call for a gradually changing effect on drilling (as the cartel gains power) and probably also a weakening of the previous positive relationship between new drilling and lagged prices (as behavioral differences appear between members of the cartel and nonmembers). Neither result seems to have occurred. The R^{-2} is not lower for equation (12) than for equation (9), but higher (.84 vs. .76). And as the reader can see from Figure 4, we do not have a gradual pivoting or shifting of the relationship between new drilling and price, but a sharp transition to a new and fundamentally different relationship at the time of the disorders: 1904 is part of the old relationship while 1905 is part of the new. We are thus inclined to downgrade the importance of the cartel for the developments examined here.

No attempt will be made here to offer general conclusions on the effects of violence in oil producing countries. It is clear that case studies of other countries are needed and that more research is required on the Russian situation in 1905. More detailed information is needed on the inventories in the interior and on the adjustments of individual users and producers of petroleum products to the crisis.

Since the market system seems to have played an important role in rationing limited supplies it would be helpful to have

Figure 4



90
80
70
60
50
40
30
20
10
0
0 4 8 12 16 20 24 28 32 36 40 44
'00
'01
'04
'07
'13
'12
'09
'08
'03
'06
'11
'10
'02
'05
New Drilling (D_t^n), thousands of sazhenes
Price of Crude Oil in Previous Year, copecks per pood

more data on prices. The appendix to this paper presents a time series for crude oil prices in Baku, but prices are also needed for kerosene, *astatki*, wood, and coal. With such information it would also be possible to learn more about the financial flows in the industry, the effects of the cartel, the impact of seasonality on the industry, and the movement of boundaries for fuel "regions".

Finally, there are other fuel crises in Russian history which might be investigated. As one indicator, during the turmoil associated with the 1917 Revolution and the civil war which followed, the share of coal in railroad fuel consumption fell from 64.2 percent of the total (1917) to 5.1 percent (1919), while the share of wood rose from 13.8 percent to 88.1 percent. [Knorre, p. 724]. In short, there are enough questions here to keep scholars busy for many years.

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APPENDIX

The purpose of this Appendix is to present a time series of crude oil prices in Baku from 1872 to 1916. Although other series are available, they are generally incomplete in coverage and come with little accompanying information on sources of information, methods of construction, or reliability.

In constructing this new series, I have chosen among competing series on the basis of the following criteria. First, if there is reason to believe that one series has been arrived at by a superior method or collected by a more reliable organization, that series is used in preference to ones of unknown or inferior quality. As an example, series denominated in measures other than the original " copecks per pood " generally have been discarded in order to avoid inaccuracies which may have arisen from the use of unknown conversion factors. An exception has been made in the case of years 1881-1886, because of the lack of acceptable alternatives.

Second, if there is no reason to prefer one series over others then all competing values have been averaged.

Third, the sources and methods used in deriving each figure in the final series have been indicated. In the small number of cases in which there was a substantial difference among competing values (i.e., when the largest exceeded the smallest by 10 percent or more), all competing values are presented in table notes.

Although some sources report price figures to three decimal places, I have presented only one decimal place and would recommend caution in using even it. No authors claimed accuracy beyond the decimal point for the years 1872-1880. In view of the methods used in deriving figures for 1881 through 1889 (see notes *a* and *b*), the user should maintain a reasonable skepticism in using these figures. Given the improvements in Russian oil industry statistics after 1889 noted by Kelly and Kano and the narrow range of differences noted here, the reader can be substantially more confident of the figures from 1890 on than for earlier years.

Symbols used to indicate sources and methods of processing competing figures are as follows:

1, 2, 3, . . . , 10:	Indicates the source of a particular figure used to construct prices for that year. See list of references at end of Appendix.
$2 = 7 = 9$:	References 2, 7, and 9 give identical prices.
$5 + 8 + 9$:	Price shown is the average of figures in references 5, 8, and 9.

Appendix Table I

PRICES OF CRUDE OIL IN BAKU
(copecks per pood)

Year	Price	Notes	
1872	45.	5 = 6	
1873	5.	5	
1874	4.	5	
1875	10.	5	
1876	5.	5	
1877	8.	5	
1878	7.	5	
1879	5.	5	
1880	3.	5	
1881	2.3	1	a
1882	2.7	1	a
1883	1.5	1	a
1884	2.6	1	a
1885	2.7	1	a
1886	1.6	1	a
1887	0.3		b
1888	0.6		b
1889	2.2		b
1890	7.5	6 + 10	c
1891	2.7	3 = 6 = 9 = 10	
1892	1.1	3 + 6 + 9 + 10	d
1893	1.4	3 = 6 = 9 = 10	
1894	3.1	3 = 6 = 9 = 10	
1895	6.6	3 + 6 + 9 + 10	
1896	7.8	3 = 6 = 7 = 9 = 10	
1897	7.7	3 = 6 = 7 = 9 = 10	
1898	9.8	3 = 6 = 7 = 9 = 10	
1899	13.9	3 + 6 + 9 + 10	
1900	15.7	2 = 3 = 6 = 7 = 9 = 10	
1901	8.1	2 + 3 + 6 + 7 + 9 + 10	
1902	6.7	2 + 3 + 6 + 7 + 9	
1903	8.9	2 + 3 + 6 + 7 + 9	e
1904	14.4	2 + 3 + 6 + 7 + 9	f
1905	19.2	2 + 6 + 7 + 9	g
1906	25.6	2 + 6 + 7 + 9	
1907	27.4	2 + 6 + 8 + 9	
1908	21.7	2 + 6 + 8 + 9	
1909	21.2	2 + 6 + 8 + 9	
1910	15.1	2 + 4 + 6 + 8 + 9	

Year	Price	Notes
1911	22.1	2 + 4 + 6 + 8 + 9
1912	34.6	2 + 4 + 6 + 8 + 9
1913	42.0	2 + 4 + 6 + 8 + 9
1914	36.2	6 + 8 + 9
1915	42.5	6 + 8 + 9
1916	46.1	6 + 9

a) Prices for 1881 through 1886 were calculated from Chambers (1887), p. 406. Chambers' original U.S. cents-per-barrel figures were converted to copecks per pood using an assumption of 8.50 poods per barrel of 42 gallons (calculated from Henry, p. 256) and foreign exchange rates reported in CHARLES GOODLET (ed.), *The Russian Journal of Financial Statistics* (St. Petersburg: G. Barbet de Vaux, Publ., 1901), p. 517. This exercise yielded prices for portions of years which were averaged using weights proportional to the length of each fraction of the total year for which prices were reported.

b) Calculated from equation (9) using drilling figures reported in Pazhitnov, p. 84. These prices should be used with particular caution.

c) Reference [6] reports 7.1 while reference [10] reports 7.8. Reference [9] reports 17.0, but comparison of intercity differentials of prices reported in [9] for 1890 and 1891 suggests that this large figure is probably a transposition of the intended figure, assumed to be 7.1.

d) References [6] and [9] report 1.0, while [3] and [10] report 1.1.

e) References [2], [3], and [7] report 9.04, while [6] reports 8.2 and [9] reports 9.1.

f) References [2], [3], and [7] report 14.67, while [6] reports 13.3 and [9] reports 14.7.

g) References [2] and [7] report 19.93, while [6] reports 17.1 and [9] reports 19.9.

APPENDIX REFERENCES

[1] CHAMBERS (1887), p. 406.

[2] GEFTER, pp. 723, 738.

[3] HENRY, p. 144.

[4] KNORRE, pp. 498, 512.

[5] MARVIN, pp. 213-14.

[6] PAZHITNOV, pp. 117, 172.

[7] THOMPSON, p. 31.

[8] U.S.S.R., Narodnyi Komissariat Finansov. *Narodnoe khoziaistvo v 1915 godu.* Petrograd: Vos'maia Gosudarstvennaia Tipografiia, 1918, p. 284.

[9] U.S.S.R., Sovet Neftianoi Promyshlennosti. *Spravochnik po neftianomu delu*, Vol. II. Moscow: Tsentral'noe Upravlenie Pechati VSNKh SSSR, 1925, p. 349.

[10] *Vestnik finansov, promyshlennosti i torgovli*, XX, No. 7 (February 16, 1903), p. 280.