

# The Russian Rouble Crisis of December 2014: Structure and Liquidity of a Foreign Exchange Market<sup>1</sup>

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We investigate the hypothesis that the Russian rouble crisis and the 40% change in the exchange rate in mid-December 2014 were caused by a large supply-demand imbalance in the foreign exchange market. Liquidity analysis shows that a \$300 million imbalance usually resulted in a 1% price change and that the price change could have been even larger with the accelerated execution of transactions. Thus, the change in the exchange rate could have been caused by the accelerated purchase of \$3–5 billion. Empirical analysis of exchange transactions indicates the existence of an imbalance, but its real size is difficult to assess due to the lack of data on off-exchange trades. The actions of the Bank of Russia during the crisis helped the market cope with the lack of foreign currency liquidity. The likelihood of recurrence of such situations in the future could be reduced if a system for monitoring imbalances is created in the foreign exchange market and mechanisms for automatically slowing down trading are introduced, such as temporary halts in trading or a switch to discrete auctions.

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*crisis, liquidity, foreign exchange market, financial stability*

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## 1. Introduction

The Russian rouble crisis in mid-December 2014 is one of the most interesting events in the modern history of the Russian financial market. The USD/RUB exchange rate rose by almost 40%, from 58 roubles/dollar at the opening of trading on Monday,

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15 December, to 80 roubles/dollar in the afternoon of Tuesday, 16 December. Economists were quick to predict a long-term, full-blown crisis (Itskhoki, 2015).

In fact, the Russian rouble crisis was not caused by fundamental problems in the economy. Despite the difficult geopolitical environment, the Russian economy was much stronger in 2014 than it was in the 1990s. A USD/RUB exchange rate over 80 roubles/dollar was observed for only a few minutes on Tuesday, 16 December, and by the close of trading on Wednesday, 17 December, the USD/RUB exchange rate had already returned to the level of 60 roubles/dollar. One particularity of the crisis was the speed at which the Russian currency first depreciated and then recovered.

The starting point of this study is the paper of Obizhaeva (2016), who, as the main hypothesis, puts forward the idea that the sharp depreciation of the Russian rouble was due to a significant imbalance in the supply of and demand for foreign currency. We consider the imbalance hypothesis as part of an analysis of the microstructure of the foreign exchange market, in particular, by studying the dynamics of liquidity and the peculiarities of market participants' transactions during the crisis.

Our empirical liquidity estimates are in line with theoretical calculations based on the invariance theory proposed by Kyle and Obizhaeva (2016). On average, the purchase of \$300 million in foreign currency led to an approximately 1% depreciation of the Russian rouble. At the same time, the change in the exchange rate might be several times greater if the purchases of foreign currency were forced and executed at an accelerated pace. Thus, the 40% depreciation of the Russian rouble could have been caused by the purchase of \$10 billion of foreign currency, executed over a few months, or by the purchase of a smaller amount, around of \$3–5 billion, executed over a few days or weeks.

Our estimates of liquidity are consistent with the expert estimates of market participants. In December 2014, Sergey Romanchuk assumed<sup>2</sup> that accelerated purchases of foreign currency over two days could rise the USD/RUB exchange rate to the level of 100 roubles/dollar, that is, by about 60%, or 1% for every \$150 million.<sup>3</sup>

We also conduct an empirical analysis of the positions of trading participants in the exchange currency market. Our research is based on a methodology pioneered by the U.S. Commodity Futures Trading Commission and the U.S. Securities and Exchange Commission to investigate the crisis in the U.S. market on 6 May 2010, which was called the Flash Crash (U.S. Commodity Futures Trading Commission and U.S. Securities and Exchange Commission, 2010a, 2010b). In particular, we study supply and demand imbalances by means of classifying all active accounts on the basis of strategies used by the traders into several groups: buyers and sellers, intermediaries, dealers, and others. Without splitting the market into segments, every transaction always has a buyer and a seller, so demand is always equal to supply in the entire sample, and it is difficult to see the imbalances.

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<sup>2</sup> See Metelitsa et al. (2014).

<sup>3</sup> In December 2014, Rosneft issued RUB625 billion in rouble-denominated bonds. It was expected that if Rosneft converted part of this Russian rouble liquidity into foreign currency to repay the foreign currency loan it received in 2013 to buy TNK-BP, this could have a material impact on the Russian rouble exchange rate.

Our analysis of transactions in the period from 1 September 2013 to 1 April 2015 shows that daily changes in the positions of foreign currency buyers and sellers usually balance one another. At the same time, significant imbalances sometimes arise in the system, which are usually reflected in the positions of dealers. Such imbalances were observed in March, October, and early December 2014. Exchange data show that from 12–19 December, a supply-demand imbalance of approximately \$3–5 billion emerged in the market. At the same time, actual imbalances may be much larger, as their real size is difficult to assess due to the lack of data on the over-the-counter (OTC) market.

During the crisis, the Bank of Russia took several measures: large-scale foreign exchange interventions on 12 and 15 December in the amount of \$4.344 billion, foreign exchange repos of \$7.065 billion on 15 and 16 December, and a sharp increase in the key rate from 10.5% to 17% on the night of Tuesday, 16 December. These measures made it possible to alleviate the lack of foreign currency liquidity in the market and, as a result, helped the market to cope with the imbalances.

Several alternative hypotheses for the Russian rouble crisis have been published in the mass media. These hypotheses all seem quite improbable.

For example, we often hear the opinion that the Russian rouble crisis was caused by the fall in oil prices. The price of oil declined for several months in 2014 – from \$115 per barrel at the end of June to \$60 per barrel at the beginning of December – but this price change was quite smooth. Modern markets react to information with minimal delays, so it is incorrect to assume that the sharp change in the Russian rouble exchange rate in mid-December could have been caused by the cumulative effect of changes in oil prices over a period of six months. Undoubtedly, these changes influenced the dynamics of the exchange rate over the same period, but they could not have been the direct cause of the sharp fluctuations in the exchange rate in mid-December, because oil prices were stable from 11 December to 18 December.

Former Finance Minister Aleksey Kudrin offered an explanation involving expectations, suggesting that the market was ‘negatively warmed up by a non-transparent deal’ of the issuance of the RUB625 billion Rosneft loan, the issue of bonds during the period of devaluation of the Russian rouble raised fears of an even greater weakening of the domestic currency due to the possible conversion of that amount into US dollars. He noted ‘that this money did not enter the market, but it became known later’, and, therefore, ‘there was an expectation effect that the exchange rate would change’.<sup>4</sup> It may be the case that expectations can cause macroeconomic crises that form and develop over several years or even decades, but expectations are unlikely to cause the micro-crises that sometimes occur in financial markets in the course of a day or even minutes. At such high frequencies, the expectations of market participants do not have time to synchronise. Traders can interpret information in different ways, make different assumptions about how other participants will react to such information, and choose trading strategies that are qualitatively and quantitatively very different, so the overall impact of their actions on prices is difficult to predict unambiguously.

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<sup>4</sup> Final Press Conference at Interfax News Agency (Interfax, 2014b).

Anticipation of an earthquake cannot destroy a house if the earthquake itself does not actually occur. The fall in prices could have occurred only as a result of a real imbalance, traces of which are visible in the exchange market data.

As the main reason for the devaluation of the Russian rouble, economist Sergey Guriev\* noted a loss of public confidence in the actions of the Bank of Russia in connection with the issuance of the Rosneft bonds, their addition to the Lombard List, and the use of them to attract US dollar liquidity from the Bank of Russia. He spoke of a ‘full-fledged economic disaster’ and criticised the regulators for providing financial support to individual firms instead of fighting inflation and for the government’s lack of a clear basis for action (Guriev\*, 2014). In fact, it is hard to believe that, in just a few days, the market could lose so much confidence in the Bank of Russia that it led to such a significant depreciation of the Russian rouble. By extension of this logic, the subsequent rapid recovery of the Russian rouble by the evening of 17 December should have indicated an equally rapid recovery of confidence in the regulators.

Our study joins the literature devoted to the study of financial crises, research such as the Pecora Report (US Senate Committee on Banking and Currency, 1934) and the paper of Friedman and Schwartz (1963), which are devoted to the 1929 crisis in the United States. Brady et al. (1988) present the results of an investigation into the causes of the 1987 crisis in the United States. Kirilenko et al. (2017) study the Flash Crash in the US on 6 May 2010. Bian et al. (2021) investigate the 2015 Chinese stock market crisis. The U.S. Department of the Treasury et al. (2015) analyse the rally in the US Treasury bond market in October 2014.

Kyle and Obizhaeva (2023) show that many well-known crises in the US stock market have occurred due to large supply-demand imbalances. Estimates of the size of the imbalances agree quite well with the values of the price changes if the invariance theory is used to estimate liquidity. For example, the 1929 crisis, like the crisis in China in 2015, occurred due to imbalances associated with the mass liquidation of margin positions. The 1987 crisis was due to imbalances caused by the sale of index futures as part of portfolio insurance strategies for pension funds.

We present similar calculations for the Russian rouble crisis in December 2014 and show that this event was comparable in scale to the crises that occurred in the United States in 1929 and 1987.

Similar cases of sharp currency depreciations have been observed in many countries (see Reinhart and Rogoff, 2009). Many of these were also caused by the market response to large imbalances in the supply of and demand for foreign currencies. The study of these events in the context of invariance theory and the identification of imbalances is an interesting area for future research.

In the final section of this paper, we make several recommendations for the prevention of similar crises in the future. These include a recommendation to introduce a system for monitoring imbalances in the foreign exchange market, as well as a mechanism for automatically suspending trading or slowing it down by switching to discrete auctions when prices change significantly.

In Section 2 we provide a description of the Russian foreign exchange market and of the data, in Section 3, we study the liquidity of the foreign exchange market, and in Section 4, we calculate the size of the imbalances that could have led to the depreciation of the Russian rouble in December 2014. In Section 5, we study the empirical properties of traders' strategies and the dynamics of liquidity. Section 6 is devoted to comparing the December 2014 Russian rouble crisis with other well-known crises. In Section 7, we make several recommendations that could help prevent or respond to similar crises in the future.

## 2. Foreign exchange market and data

### 2.1. Foreign exchange market

The Russian foreign exchange market emerged in 1992, replacing the Gosbank currency exchange. The main transactions were made on the Moscow Interbank Currency Exchange (MICEX), where only banks were allowed to trade at first. The Moscow Exchange was founded in December 2011 as a result of the merger of two exchanges – MICEX and RTS. Direct access to the electronic trading platform was given not only to banks, but also to other financial institutions. At the same time, legal entities and individuals gained client access to the foreign exchange market and, therefore, conducted their transactions through brokers.<sup>5</sup>

In most countries, the bulk of currency trading takes place through OTC platforms and is practically unregulated. It is a peculiarity of the Russian foreign exchange market that liquidity is concentrated on the centralised platform of the Moscow Exchange. In 2014, most of the currency trading on the Moscow Exchange was executed in the US dollar/Russian rouble pair (approximately 90% of all transactions) and was conducted using several instruments.

Spot contracts were one of the most popular instruments on the foreign exchange market. A USDRUB\_TOM spot contract is executed upon conclusion, with currency delivery on the following day at the price specified in the Tomorrow transaction concluded. Two less liquid spot contracts (USDRUB\_TOD and USDRUB\_SPT) are executed with delivery on the day the transaction is closed at the Today exchange rate or on the second day after trading at the Spot exchange rate. The trade volume of these types of spot transactions constituted 75%, 25%, and less than 1% of the total trade volume of spot transactions, respectively.

The Moscow Exchange derivatives market also traded several cash-settled USD/RUB futures contracts with delivery dates in September (SiU), December (SiZ), March (SiH), and June (SiM). The final day on which transactions under such contracts could be made was the 15th day of the corresponding month (for example, 15 December 2014), or the first day after it.

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<sup>5</sup> In 2017, a number of large legal entities gained direct access to the foreign exchange market (Moscow Exchange, 2017), while individuals continued to trade on the exchange through brokers.

Table 1 presents estimated parameters for the volume of trade in the US dollar/Russian rouble pair for the main instruments on the Moscow Exchange at the beginning of the crisis (beginning of December 2014).

**Table 1.** Volume of trade in US dollar/Russian rouble currency pair on Moscow Exchange, \$ billion

	Instrument	Volume of trade per day
Foreign exchange market	USDRUB_TOM	4
	USDRUB_TOD	2
	USDRUB_SPT	0.01
Derivatives market	USDRUB(Si) Futures	3

*Source: Moscow Exchange, authors' calculations*

Without information about the correspondence of numbered accounts on the foreign exchange and derivatives markets, joint analysis of these markets is problematic, so our empirical analysis is based on data for USDRUB\_TOM spot contracts, where most of the liquidity is concentrated.<sup>6</sup>

Our study does not include options on currency futures or RTS index futures, which were pegged to the US dollar capitalisation of the Russian stock market and, therefore, carried both stock market and currency risk. The volume of trade in these instruments was far lower than the volume of trade in the foreign exchange market.

Our study also does not include FX swaps (TodTom, TomSpt, Tom1w, Tom2w, Tom1m, Tom2m, Tom3m, Tom6m, Tom9m, Tom1y). These financial instruments are a combination of spot contracts and reverse forward contracts, and they are often used by traders to change the term structure of currency risks, as, in combination with spot contracts, they can be used to create forward contracts with longer expiration times.

We do not consider trading in Russian currency on the trading floors in Chicago or London. The trade volumes on foreign exchanges were quite small compared to the volumes of trade on the Moscow Exchange, and these exchanges did not see a notable increase in trade volumes during the crisis in December 2014.

We also do not consider OTC platforms such as the EBS or Reuters Matching platforms. Their share in the turnover in the US dollar/Russian rouble currency pair was significant, but it was significantly less than their share in the turnover of foreign exchange instruments in other countries. According to the Bank of Russia, the volume of OTC transactions was approximately \$10 billion per day, but more detailed information about the OTC segment of the foreign exchange market in 2014 is not available in open sources.<sup>7</sup>

<sup>6</sup> Separate analysis also shows that the futures market was dominated by traders who trade intraday and have little effect on daily position changes.

<sup>7</sup> According to the Bank of Russia, in April 2015, the turnover on Direct Transactions (cash and forward transactions) amounted to \$194 billion over 22 business days, that is, approximately \$10 billion per day (see The Structure of Currency Turnover by Cash Transactions and Forward Contracts in April 2015, [https://cbr.ru/vfs/statistics/credit\\_statistics/turnover-b/turnover\\_bis\\_public\\_042015.xlsx](https://cbr.ru/vfs/statistics/credit_statistics/turnover-b/turnover_bis_public_042015.xlsx)).

In our theoretical estimates of liquidity, we use an expert estimate of the volume of trade in the aggregated foreign exchange market in 2014, approximately \$10 billion per day. This estimate includes the volume of exchange and OTC trades, but excludes synthetic swaps and intermediary transactions (of market makers and high-frequency traders). More specifically, we add up the \$9 billion per day in the exchange market (the forex and derivatives markets, see Table 1) and half of the \$10 billion per day in the OTC market (i.e. volume of trade minus synthetic swaps), and subtract intermediary transactions, which account for approximately 25% of all transactions (i.e. the share of the transactions of market makers and high-frequency traders; see Section 5.2). Thus, we obtain estimate  $V^{\$}$  of the total volume of the foreign exchange market at the beginning of the crisis:

$$V^{\$} := (9 + 10/2) \times (1 - 0.25) \approx \$10 \text{ billion per day.} \quad (1)$$

We estimate daily foreign exchange market volatility  $\sigma$  at 2%:

$$\sigma := 2\%. \quad (2)$$

## 2.2. Data

We use data on all transactions involving the main trading instruments in the US dollar/Russian rouble pair executed in the foreign exchange market of the Moscow Exchange during the period from 1 September 2013 to 1 April 2015 during trading sessions from 10:00 a.m. to 6:50 p.m.

The database includes the following information for each transaction: (1) instrument code, (2) account code, (3) transaction date and time, (4) transaction price, (5) transaction volume, and (6) transaction direction (buy or sell).<sup>8</sup> The anonymised data make it possible to reconstruct the actions of each trading participant and analyse the events of mid-December 2014 in detail.

To analyse instant liquidity, we use minute-aggregated sections of the order book for the Moscow Exchange's foreign exchange market, which consist of the following fields: (1) instrument code, (2) cut-off time (beginning of each trading minute), (3) price level, (4) aggregated number of all orders at a given price level, and (5) price level direction (buy or sell).

We also use information on daily foreign exchange interventions by the Bank of Russia from the regulator's website.<sup>9</sup>

## 3. Liquidity estimates

To assess the ability of the foreign exchange market to absorb supply-demand imbalances, we present two empirical estimates of the liquidity of the foreign exchange market and one theoretical estimate.

<sup>8</sup> The data contain information about the legal status of the account (bank, financial firm, individual, etc.) and information about the hierarchical status of the account (direct trading participant or client), but we do not use it.

<sup>9</sup> See [https://www.cbr.ru/eng/archive/db/valint\\_day/](https://www.cbr.ru/eng/archive/db/valint_day/)

### 3.1. Liquidity estimate according to order book

The first empirical estimate of market depth is calculated from the liquidity actually available in the USDRUB\_TOM market order book.

In particular, parameter  $D_{\%x}$  is defined as the US dollar volume of orders available in the order book during the interval which are  $x\%$  away from the current market price. For example,  $D_{\%1}$  shows the US dollar volume that can be bought or sold without shifting the market price by more than 1%.

We estimate the average value of parameter  $D_{\%1}$  on one-minute sections of the order book for trading sessions from 10:00 a.m. to 6:50 p.m. during the period from November 2014 to April 2015 and get  $\hat{D}_{\%1} = \$35$  million, which means that, during the specified period, a one-time purchase or sale of \$35 million resulted in a 1% price shift:

$$\hat{D}_{\%1} = \$35 \text{ million.} \quad (3)$$

This estimate of  $\hat{D}_{\%1}$  is an underestimation of liquidity. It implies instant execution of the entire volume. In reality, market liquidity is greater than the part that is visible in the order book. To take advantage of unobserved liquidity, market participants usually do not execute orders immediately, but stretch their execution over a certain period of time.

### 3.2. Liquidity estimate based on price changes and imbalances

The second empirical estimate of liquidity is calculated as the sensitivity of the Russian rouble exchange rate to imbalances.

Following the methodology proposed by Breen et al. (2002), for each day  $t$  and each hour  $h$  from 10:00 a.m. to 6:00 p.m., for the USDRUB\_TOM market, we calculate imbalances in purchases and sales of US dollars  $Imbalance_{th}^{\$}$ , based on all transactions, as the sum of all transactions  $i$  in the amount of  $V_{th,i}^{\$}$  US dollars made in hour  $h$  on day  $t$ ; sign identifier  $d_{th,i}$  determines whether a given transaction  $i$  fell into a non-increasing price interval (sell,  $d_{th,i} = -1$ ) or a non-decreasing price interval (buy,  $d_{th,i} = 1$ ):

$$Imbalance_{th}^{\$} = \sum d_{th,i} \times V_{th,i}^{\$}. \quad (4)$$

This transaction classification is traditionally used to determine the initiating party in a transaction, that is, whether the transaction was initiated by the buyer or the seller. It should be noted that it is approximate and inaccurate.

We then estimate the sensitivity of price changes in hour  $h$  of day  $t$  to imbalances using the regression equation:

$$\frac{\Delta P_{th}}{P_{th}} = \beta \times Imbalance_{th}^{\$} + \epsilon_{th}. \quad (5)$$

Coefficient  $\beta$  is inversely proportional to the depth of the market, that is, the larger this coefficient, the less liquid the market.

In our sample, we estimate coefficient  $\hat{\beta} = 0.000024 \times 10^{-6}$ . Thus,

$$\hat{D}_{\%1} := 1/\hat{\beta} \times 0.01 \approx \$400 \text{ million}, \quad (6)$$

that is, on average, the exchange rate changed by 1% with imbalances of \$400 million.

This estimation of  $\hat{D}_{\%1}$  is an overestimation of liquidity. First, the error in classifying the transaction markers leads to error in determining the imbalances. This leads to a downward bias in the estimate of coefficient  $\beta$  in the evaluation of regression equation (5), which, in turn, leads to an upward bias in liquidity estimates  $\hat{D}_{\%1}$ .

Second, transactions cannot be considered exogenous. In particular, we can observe only a part of all originally planned transactions. We do not observe 'expensive' orders, because, under adverse conditions, trading participants often decide not to execute planned transactions. For example, they reduce their purchase volumes when the price has risen too much. Conversely, we see too many 'cheap' orders, because, under favourable conditions, trading participants often decide to execute larger transactions, such as by increasing purchase volumes when the price is falling. The endogeneity of the regressor in equation (5) leads to an overestimation of  $\hat{D}_{\%1}$  compared to the actual liquidity.

### 3.3. Theoretical liquidity estimate

The third market depth estimate is based on the invariance theory of Kyle and Obizhaeva (2016). This theory is that, despite their apparent diversity, all financial markets operate on the basis of the same fundamental principles. The diversity of markets is due to the differences in the speed at which they operate and the fact that the business time of financial markets differs from calendar time and flows at different speeds. In liquid markets, processes occur quickly, while in illiquid markets, the same processes take longer.

We denote the duration of a business day as  $H$  calendar days. If  $V^{\$}$  is the US dollar volume of trade on one calendar day and  $\sigma$  is the daily percentage volatility, then the total volume of trade on one business day is  $V^{\$} \times H$  US dollars, and the volatility for a business day is  $\sigma\sqrt{H}$ .

Kyle and Obizhaeva (2016) show that the length of the business day non-linearly depends on volume of trade  $V^{\$}$  and volatility  $\sigma$  as follows:

$$H \sim (V^{\$} \times \sigma)^{-2/3}. \quad (7)$$

With higher volatility and volumes of trade, the actual business day is shorter, trading takes place more quickly, and the market is more liquid.

Invariance theory further states that market depth is invariant in business time, i.e. the execution of the same percentage of the total volume of trade in business time  $V^{\$} \times H$  results in the same price shift as the percentage of volatility in business time  $\sigma\sqrt{H}$ .

Thus, the execution of an order of size  $Q$  should lead to a percentage change in price of  $\Delta \ln P$ :

$$\Delta \ln P \sim \sigma\sqrt{H} \times \frac{Q}{V^{\$}H}. \quad (8)$$

Taking into account (7), the hypothesis of invariance leads to quantitative formulas for the depth of markets with different volumes of trade and volatility.

A purchase of  $Q$  US dollars will lead to a percentage drop in the Russian rouble exchange rate of  $\Delta \ln P$ , which can be determined by the formula

$$\Delta \ln P = 5 \times 10^{-4} \times \left( \frac{V^{\$}}{40 \times 10^6} \right)^{1/3} \times \left( \frac{\sigma}{0.02} \right)^{4/3} \times \frac{Q}{0.01 \times V^{\$}}, \quad (9)$$

where the proportionality coefficient value is calibrated on data for the US stock market for the period from 2001 to 2005.

For example, if we assume that the exchange rate volatility is  $\sigma = 2\%$  per day and the average daily volume of trade in the foreign exchange market is  $V^{\$} = \$10$  billion, then an imbalance of  $Q = \$300$  million will lead to a change in the exchange rate of about 1%:

$$\begin{aligned} \Delta \ln P = 5 \times 10^{-4} \times \left( \frac{10 \times 10^9}{40 \times 10^6} \right)^{1/3} \times \left( \frac{0.02}{0.02} \right)^{4/3} \\ \times \frac{300 \times 10^6}{0.01 \times 10 \times 10^9} \approx 1\%. \end{aligned} \quad (10)$$

Thus, the theoretical estimate of  $\hat{D}_{\%1}$  is \$300 million:

$$\hat{D}_{\%1} = \$300 \text{ million}. \quad (11)$$

This theoretical estimate is based on the liquidity of the entire USD/RUB foreign exchange market, while the two empirical valuations are based on data for USDRUB\_TOM spot contracts and, therefore, account only for liquidity in a subset of the market.

### 3.4. Summary table of liquidity estimates

Table 2 presents the summary results of liquidity estimates  $\hat{D}_{\%1}$ . The theoretical liquidity estimate (\$300 million) is higher than the bottom empirical estimate (\$35 million) created from sections of the order book, but it is lower than the top empirical estimate (\$400 million) built on price sensitivity to reconstructed supply-demand imbalances.

**Table 2.** Estimates of foreign exchange market liquidity

Estimate	Market	Shift	Depth $\hat{D}$ , \$ million
Empirical estimate according to order book	USDRUB_TOM	Downward	35
Empirical estimate according to imbalances	USDRUB_TOM	Upward	400
Theoretical estimate	Entire USD/RUB FX Market	No shift	300

Source: authors' calculations

In further calculations, we use a theoretical estimate of  $\hat{D}_{\%1} = \$300$  million, that is, we believe that the execution of a \$300 million transaction will lead to a 1% price change.

### 3.5. Liquidity and order execution speed

The theoretical estimate of liquidity using formula (9) assumes that transactions are executed at a natural speed and that the market has time to 'digest' them.

In fact, transaction execution speed is an important parameter that affects the magnitude of price changes. Execution that is too fast results in the market not having time to absorb imbalances, and this causes short-term price spikes. For example, the purchase of a certain fixed amount of US dollars over a few minutes will result in a larger price change than the same purchase over a few days.

There is no consensus among researchers on how order execution speed affects price changes. In the empirical study by Almgren et al. (2005), increasing order execution speed by  $\alpha$  times increases the magnitude of price change by  $\alpha^{0.60}$  times. In the theoretical model of Kyle et al. (2017) price changes increase linearly with execution speed, i.e.  $\alpha$  times. For example, executing an order  $\alpha = 10$  times faster than usual may further increase the price jump by  $\alpha^{0.60} = 10^{0.60} \approx 4$  times or  $\alpha = 10$  times.

We have adapted formula (9) to include the dependence on a speed of execution  $\alpha$  times faster than usual as additional factor  $\alpha^{0.60}$ :

$$\Delta \ln P = 5 \times 10^{-4} \times \left( \frac{V^{\$}}{40 \times 10^6} \right)^{1/3} \times \left( \frac{\sigma}{0.02} \right)^{4/3} \times \frac{Q}{0.01 \times V^{\$}} \times \alpha^{0.60}. \quad (12)$$

For example, if the USD/RUB exchange rate is 58 roubles/dollar, the volume of daily trading in the foreign exchange market is \$10 billion, and the daily exchange rate volatility is 2%, then the execution of an order to buy US dollars in the amount of \$3 billion at ten times faster than the normal speed (over 1–2 days instead of 18 days) will lead to a depreciation of the Russian rouble by about 38%:

$$\begin{aligned} \Delta \ln P = 5 \times 10^{-4} \times \left( \frac{10 \times 10^9}{40 \times 10^6} \right)^{1/3} \times \left( \frac{0.02}{0.02} \right)^{4/3} \\ \times \frac{3 \times 10^9}{0.01 \times 10 \times 10^9} \times 10^{0.60} \approx 38\%. \end{aligned} \quad (13)$$

Next, we analyse imbalances that could have led to the weakening of the Russian rouble in mid-December 2014.

## 4. Estimates of possible imbalances

In mid-December 2014, the USD/RUB exchange rate changed from 58 roubles/dollar to 80 roubles/dollar, i.e. by 40%. Based on our liquidity estimates, what value of imbalance could have led to such a jump in the exchange rate?

Table 3 shows how the US dollar exchange rate changes depending on the size of imbalance and the transaction execution speed. Formula (12) is used in the calculations, and it is assumed that average daily volume of trade in the Russian foreign exchange market  $V^{\$}$  is \$10 billion and that daily volatility of price  $\sigma$  is 2%.

**Table 3.** Imbalances and estimates of changes in exchange rate,  $V^{\$} = \$10 \times 10^9$ ,  $\sigma = 0.02$

Value of imbalance (\$ billion)	Natural execution time (days)	Exchange rate change (%), for the given ratio of execution speed to natural speed				
		× 1	× 2	× 5	× 10	× 15
1	6	3	5	8	13	16
2	12	6	10	17	25	32
3	18	9	14	25	<b>38</b>	48
5	30	16	24	<b>41</b>	63	80
8	48	25	<b>38</b>	66	100	128
10	60	31	48	83	125	160

Note: The bold type in the table indicates imbalances that could theoretically lead to a 40% change in the exchange rate (the change in the exchange rate recorded on 15–16 December 2014).

Source: authors' calculations

The first column of Table 3 shows hypothetical imbalances from \$1 billion to \$10 billion. The second column shows the values of the natural execution horizon.<sup>10</sup> Columns three through seven indicate possible transaction execution speeds  $\alpha$  from  $\times 1$  to  $\times 15$  the natural speed. Exchange rate changes increase with the size of orders (from the first line to the last line) and with the speed of execution (from the third column to the seventh column).

The estimates depend on assumptions and inputs, but they show the approximate range of imbalance amounts that could theoretically have led to the 40% change in the exchange rate. For example, it could have been

- An \$8 billion imbalance executed over 24 days, that is, twice as fast as the natural horizon of 48 days,
- A \$5 billion imbalance executed over six days, i.e. five times faster than the natural horizon of 30 days,
- Or a \$3 billion imbalance executed over two days, that is, about ten times faster than the natural horizon of 18 days.

<sup>10</sup> It is known that \$4 billion transactions were typically executed in the US stock and index futures market in one day. Since the volume of trade in this market was about 30 times greater than the volume in the Russian foreign exchange market, and it had half the volatility of the Russian market, this market operated six times faster than the Russian foreign exchange market. It can be assumed that the 'natural' execution time of a transaction of a similar size (\$1 billion) in the Russian foreign exchange market during the study period was six days and that the natural execution time of other transactions increases in proportion to their size, that is, the natural execution time of a \$3 billion transaction works out to 18 days.

Since the crisis took place within a week, the crisis was most likely caused by a forced purchase of \$3–5 billion over 2–6 days.

Our calculations are approximate, and they partially rely on expert estimates, since we do not exactly know, first, the natural order execution speed in the Russian rouble market, and second, the size of market volume to use in the calculations (since it is not completely clear how to correctly determine the boundaries of the foreign exchange market or which instruments and trading platforms to include in it).

## 5. Empirical analysis of imbalances and liquidity

Next, we provide an empirical analysis of the dynamics of supply-demand imbalances, as well as an analysis of liquidity in the foreign exchange market for the period from 1 September 2013 to 1 April 2015. To analyse imbalances, we use the methodology proposed by Kirilenko et al. (2017) to analyse the crisis that occurred in the United States on 6 May 2010, known as the Flash Crash, but we adapt it to the particularities of the Russian foreign exchange market.

### 5.1. Classification of market participants

Trading participants vary widely in their goals, size, and strategies. We conduct an empirical analysis of strategy profiles from 1 September 2013 to 1 April 2015 and classify all accounts into several groups.<sup>11</sup>

This approach is more accurate than the classification of accounts based on formal definitions. For example, it is sometimes the case that a trading participant has the formal status of a market maker, as it participates in the Moscow Exchange Market Making programme, but in reality its strategies differ greatly from those of market makers.

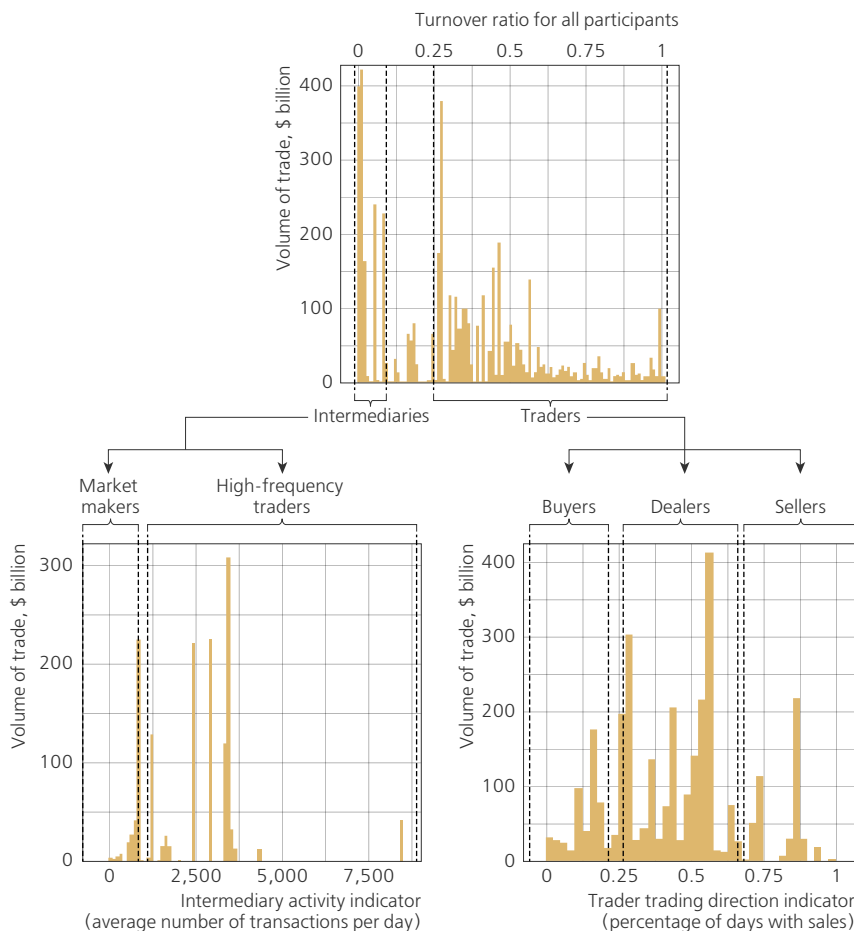
The accounts are classified based on the characteristics of their strategy profiles. Figure 1 illustrates the classification algorithm. For each account  $i$  and each day  $t$ , we calculate several characteristics related to the level of activity and direction of the strategies:

- $Vol_{t,i}$  is the daily volume of trade expressed in US dollars;
- $Inv_{t,i}$  is the position in US dollars at the end of the trading day (may be positive or negative, depending on the direction of trading that day);
- $|Inv_{t,i}^{max}|$  is the largest value of the position in US dollars during the trading day in absolute terms;

<sup>11</sup> This classification reflects the ultimate beneficiaries of the transactions, and not the direct holders of the accounts with the Moscow Exchange, who mostly perform intermediary functions. For example, if an exporting firm had a subsidiary bank, through which it performed transactions on the exchange, then in the classification of this bank, it is likely that it will fall into the group with behaviour common to exporting firms. Or if the investment division of a large bank received orders from many clients and then closed its currency position on the Moscow Exchange, then the account of this bank will fall into the group with behaviour common to its largest clients.

- $|Inv|_{t,i}^{max}/Vol_{t,i}$  is an indicator of multidirectional trading during the day or the inverse position turnover ratio (small values of this characteristic with a large volume indicate intensive position turnover, which is usual for intermediaries);
- $N_{t,i}$  is the number of transactions for the day.

**Figure 1.** Distribution of volume of trade by group



Note: Accounts are classified based on the following parameters: frequency and size of transactions, direction, and position turnover ratio  $|Inv|_{t,i}^{max}/Vol_{t,i}$  (the lower the ratio, the higher the turnover).

Source: compiled by the authors

After aggregating the daily characteristics, the accounts are sorted into several groups.

**Group 1: Buyers and sellers.** Buyers and sellers are professional trading participants who regularly either buy or sell foreign currency. We classify their

accounts as the accounts of buyers and sellers of foreign currency depending on the direction of trading. In particular, the group of accounts of buyers includes accounts with low turnover of positions ( $|Inv|_{t,i}^{max}/Vol_{t,i} > 0.20$ ), from which the foreign currency was bought, that is

$$Inv_{t,i} > 0, \quad (14)$$

during 80% of the total number of trading days included in the sample. The group of seller accounts includes accounts with low turnover of positions from which the foreign currency was sold during 70% of the days:<sup>12</sup>

$$Inv_{t,i} < 0. \quad (15)$$

Foreign currency sellers' accounts may be owned by exporters who regularly received revenue in foreign currency and converted it into Russian roubles to pay taxes and cover costs expressed in Russian roubles. Foreign currency buyers' accounts may be owned by importers who regularly bought foreign currency to finance purchases of equipment and components from abroad.

It is worth noting that the Bank of Russia most likely falls into the group of foreign currency sellers, since, for most of the study period, it sold foreign currency to support the Russian rouble exchange rate: the final transition to a floating rouble exchange rate took place only on 10 November 2014.

**Group 2: Intermediaries (market makers and high-frequency traders).**

Intermediaries are professional trading participants who, if necessary, provide liquidity and help smooth out foreign currency supply-demand imbalances between sellers and buyers. Intermediaries try to make money on the difference between the purchase and sale prices by closing positions at the end of the day. In particular, this group includes accounts with high position turnover, for which, during 70% of days,

$$|Inv|_{t,i}^{max}/Vol_{t,i} < 0.05. \quad (16)$$

Depending on level of activity, intermediary accounts are further sorted into market makers, if their average number of transactions  $N_{t,i}$  was less than 2,000 per day,

$$N_{t,i} < 2,000, \quad (17)$$

and high-frequency traders, if their average number of transactions  $N_{t,i}$  was more than 2,000 per day,

$$N_{t,i} > 2,000. \quad (18)$$

**Group 3: Dealers.** Dealers are professional trading participants who participate in the global capital market and also trade to manage currency risks. The transactions of these participants usually do not have a constant focus and depend on the situation in the financial markets. In particular, this group of

<sup>12</sup> These thresholds are chosen in view of the data clusters.

accounts includes accounts with low position turnover and highly multidirectional trading, that is, accounts with an average

$$|Inv|_{t,i}^{\max} / Vol_{t,i} > 0.20, \quad (19)$$

but which are not included in the group of buyers and sellers.

We also distinguish a small (in terms of the number of participants) group of large dealers (whose average daily trading volume is more than \$100 million) among these accounts, which most likely consists of the accounts of large Russian banks with investment divisions that received large orders from corporations and executed them on the foreign exchange market. We label the remaining dealers ‘small’ dealers (whose average daily trading volume is less than \$100 million).

**Group 4: Other traders.** This group of accounts includes other accounts with small numbers of active days and small numbers of transactions per day (less than \$10,000), as well as all other accounts that are not included in the previous groups.

## 5.2. Characteristics of groups of trading participants

In this section, we analyse the properties of the strategies of each group of traders and how these properties change over time.

Table 4 shows summary statistics for each group of accounts for the period from 1 September 2013 to 1 April 2015: average total trading volume per day, average position at the end of the day, average number of accounts, average number of transactions per day from each account, and number of changes in trading direction per day (that is, a change in direction from buying to selling, and vice versa).

**Table 4.** Strategy parameters for each group of accounts

Group	Daily trading volume (\$ billion)	Position at end of day (\$ million)	Number of accounts	Number of transactions from account per day	Number of changes in direction per day
Buyers	1.1	439	172	13	2
Sellers	1.2	–633	26	29	3
High-frequency traders	1.9	0.0	4	2,964	837
Market makers	0.9	0.1	12	290	115
Large dealers	4.4	86	28	487	55
Small dealers	1.2	81	483	12	4
Other traders	2.0	28	311	4	2

Source: authors' calculations

As follows from Table 4, in the period under review (from 1 September 2013 to 1 April 2015), there were many more buyers of foreign currency than sellers, usually, around 172 accounts bought foreign currency, while only 26 accounts sold foreign currency. This is consistent with the interpretation of the accounts as those owned by importers and exporters, respectively, since their number is roughly the same as the

number of large importers and exporters during that period. On average as a group, buyers bought approximately \$439 million per day (approximately \$2.5 million per day for each of the 172 accounts). Sellers sold approximately \$633 million per day (approximately \$30 million per day for each of the 26 accounts).

The group of large and small dealers smoothed out imbalances by buying roughly \$170 million per day. There were 28 large dealers and 483 small dealers in the market.

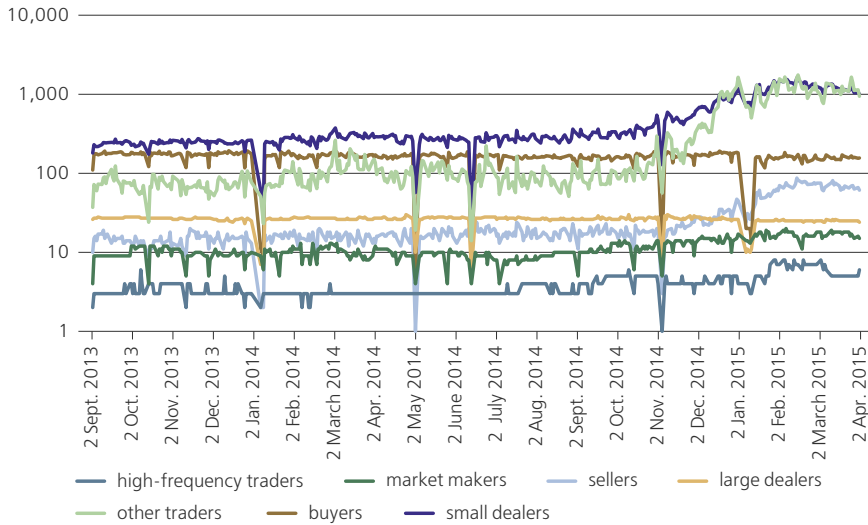
There were typically about twelve active market makers and four active high-frequency traders in the market. Despite the fact that the market makers and high-frequency traders traded a lot during the day, their positions did not change at the end of the day: these intermediaries only smoothed out the supply-demand imbalances between buyers, sellers, and dealers within the trading session.

The interventions of the Bank of Russia amounted to approximately \$75 billion for the entire period from 1 September 2013 to 1 April 2015. At the same time, half of all the interventions fell on a few days in March and October 2014 when material imbalances formed in the market. With the exception of a few days, even without the participation of the Bank of Russia, the natural demand from buyers and dealers was approximately comparable to the natural supply from sellers, so there was no material imbalance in the market that could greatly affect the exchange rate of the Russian rouble.

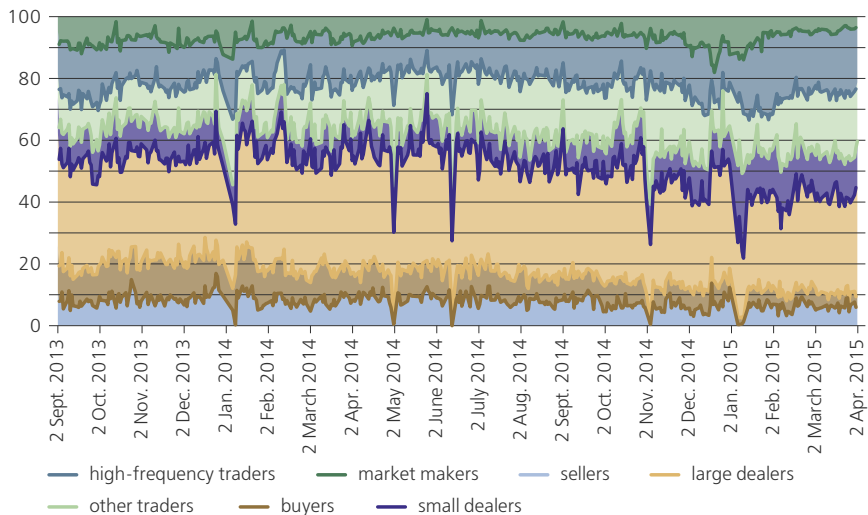
Figure 2 shows how the number of active accounts in each group changed during the study period. The number of buyers, sellers, large dealers, and intermediaries remained almost unchanged. In this, however, the activity of large dealers, buyers, and sellers sharply decreased during the holidays in January, May, June, and November. There has been a notable increase in the number of active accounts of foreign currency sellers, other traders, and small dealers since November 2014, but the reasons for this increase are difficult to determine.

Figure 3 shows how each group's share of the daily trade volume changed over the same period. The buyers and sellers together accounted for approximately 20% of the volume of trade, and their combined share of participation decreased slightly over the entire period. The share of intermediaries (market makers and high-frequency traders) was approximately 25% and increased notably during the periods of instability, in March and December 2014. High-frequency traders generated approximately two-thirds of the volume of all intermediary transactions. The share of dealers was approximately 40% of the total volume of trade. Finally, about 15% came from other traders. From time to time, their transactions partially covered the shortfall of trading volume of buyers, sellers, and dealers.

We analyse how much risk, on average, various groups of market participants took on and how much liquidity they could potentially provide to the market. For each day and each group of accounts, we count the intraday positions accumulated from the beginning of the day to the end of each hour within the trading session. After that, for each group, we fix the hour and calculate the average value for this hour for all days, along with the distribution percentiles.

**Figure 2.** Number of active accounts by group

Source: authors' calculations

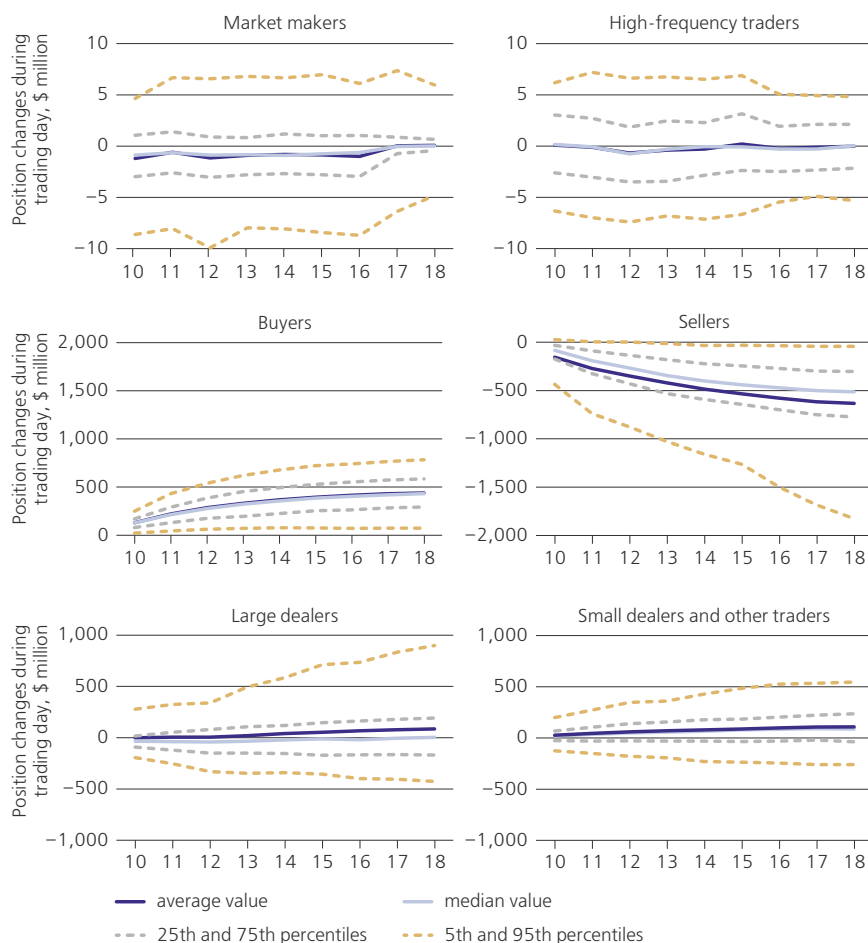
**Figure 3.** Share of trading volume of each group of accounts in total volume, %

Source: authors' calculations

Figure 4 shows how the aggregated positions changed on average by group for each hour of the trading sessions from 10:00 a.m. to 6:50 p.m. The positions of the intermediaries (market makers and high-frequency traders) remained near zero during all trading sessions. The positions of the buyers gradually increased during the trading sessions, while the positions of the sellers gradually decreased.

The dealers and other traders (see the two bottom charts in Figure 4) had a slight tendency to buy dollars, which offset the small difference between the buying and selling transactions.

**Figure 4.** Average changes in intraday position by account group, \$ million



Source: authors' calculations

Table 5 shows the maximum sizes of positions that were opened within the trading session for each group (95% confidence intervals of the position accumulated). The maximum open positions of intermediaries were only \$7 million for market makers and \$7 million for high-frequency traders. These positions were much smaller than the average positions accumulated during the trading session by buyers, sellers, and large dealers (\$439 million, \$633 million, and \$86 million, respectively).

**Table 5.** Maximum and minimum position sizes by account group (at end of hour)

Group	Average position at end of day (\$ million)	Maximum 95th percentile position at end of hour (\$ million)	Minimum 5th percentile position at end of hour (\$ million)
Buyers	439	785	22
Sellers	–633	–27	–1,826
High-frequency traders	0.0	7	–7
Market makers	0.1	7	–10
Large dealers	86	899	–427
Small dealers	81	384	–174
Other traders	28	162	–103

*Source: authors' calculations*

Thus, intermediaries did not have much potential or ability to absorb imbalances. They could help absorb small imbalances (of no more than \$14 million) during trading sessions, but they could not provide the market with the necessary amount of liquidity in the large imbalances that were observed in March, October, and December 2014.

### 5.3. Dynamics of changes in trader positions

Figure 5 shows the dynamics of the positions accumulated for each group of market participants for the period from January to December 2014, calculated as the total volume of all purchase transactions minus all sales transactions within each group.

Positive numbers represent purchases, and negative numbers represent sales. By definition, the number of purchases is always equal to the number of sales, and the sum of the positive and negative volumes is always zero, so it is important to segment the accounts into groups and analyse the data for each group separately.

The buyers' accumulated position grew smoothly and reached \$115 billion at the end of the period, while the sellers' accumulated position gradually decreased to \$100 billion over the same period. At the same time, at any given point in the period, the total position of sellers and buyers was approximately equal to zero.

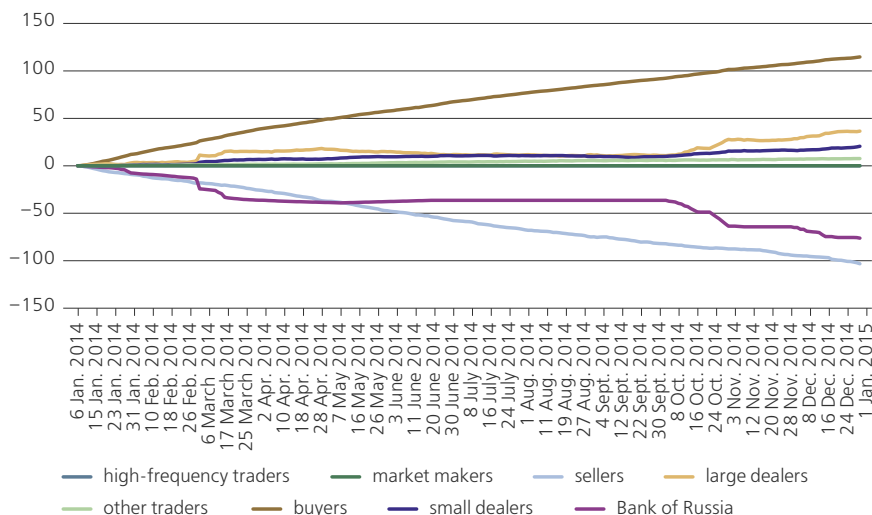
Even though the transactions of market makers and high-frequency traders accounted for a significant share of the volume of trade, their impact on the overall imbalance was negligible. These market participants usually close their positions at the end of the day and have practically no effect on the exchange rate of the Russian rouble.

The total position of the small dealers also remained marginal compared to the changes in the positions of the buyers and sellers, although they did slightly increase their US dollar position throughout the period.

Figure 6 shows the dynamics of the changes in the positions for each day for each group in the period from September 2013 to April 2015. Daily buying by buyers and daily selling by sellers approximately balanced one another (the brown and light blue). These amounts decreased notably in the second half

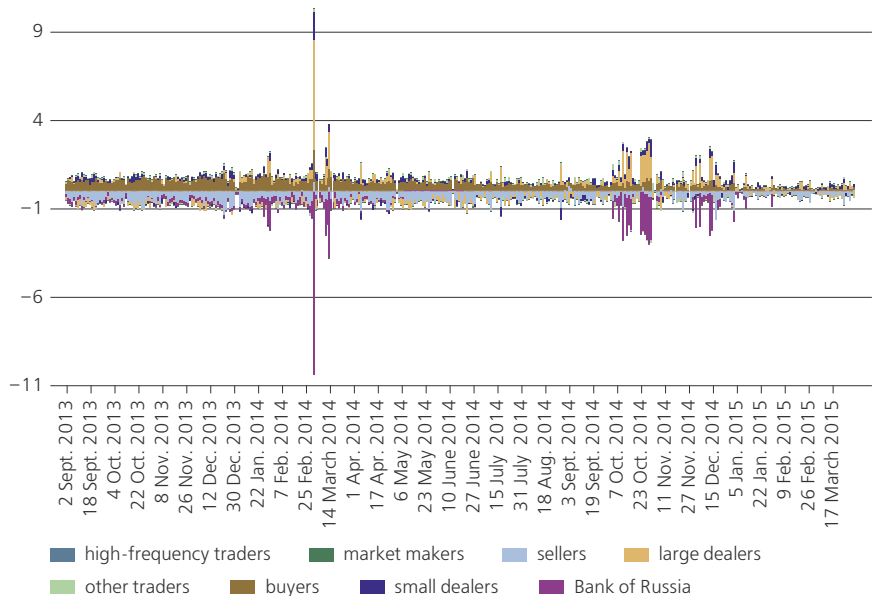
of 2014, indicating a general slowdown in the growth of the Russian economy. Dealer transactions also balanced one another.

**Figure 5.** Total positions accumulated for each account group, \$ billion



Source: authors' calculations

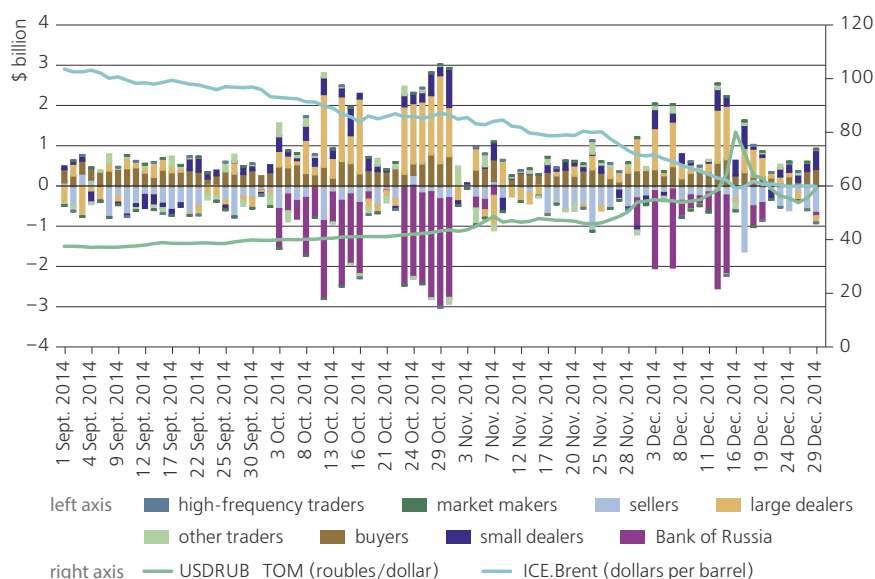
**Figure 6.** Daily changes in positions of each account group, \$ billion



Source: authors' calculations

The periods of material imbalances stand out sharply against the general background. The peak in sales by the Bank of Russia (and, accordingly, in the purchases of all other participants) fell on 3 March 2014, at \$10 billion. This imbalance was associated with the Crimean events and a material outflow of capital from Russia. On this day, foreign currency was bought by almost all groups of accounts. A series of smaller imbalances is also observed in mid-March 2014, and the next significant imbalances are observed in 2014Q4.

**Figure 7.** Daily changes in positions of each account group, US dollar exchange rate and Brent oil price from September to December 2014



Source: authors' calculations

Figure 7 shows in more detail the daily changes in the positions of each group from September to December 2014. The daily changes in positions are shown in billion US dollars (left axis), and the dynamics of the USD/RUB exchange rate and the price of a barrel of oil in US dollars (right axis) are also shown. The chart shows large imbalances in October and December 2014, which occurred due to purchases of US dollar liquidity by large dealers, which led to sharp positive changes in their positions. In this, the foreign currency purchases of large dealers were not segregated, but crowded, which may indicate that the large transactions flowing through their accounts were not implemented instantly but were distributed over time. Most of these imbalances were absorbed by the Bank of Russia.

For example, from 10–16 October 2014, there were imbalances in the positions of the dealers in the amount of approximately \$7 billion, and in the period from 23–30 October, there were imbalances totalling approximately \$9 billion, with

large dealers (and smaller dealers) systematically buying \$1.5 billion every six trading days during that period. In addition, there were small imbalances totalling up to \$2 billion on 3 December and 5 December.

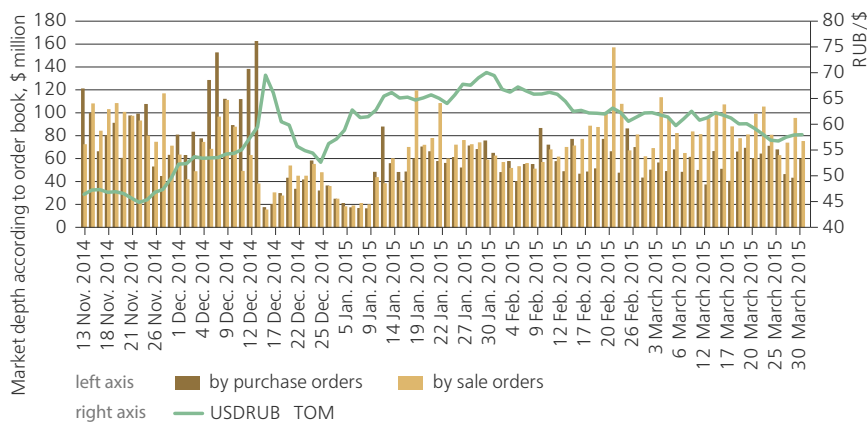
From 12–19 December 2014, during the Russian rouble crisis, there was a surge in purchases of US dollars in the positions of large dealers. Its magnitude was approximately \$5.5 billion, of which \$3.5 billion fell on 12 December and 15 December and about \$2 billion fell on 17–19 December. For several days in mid-December, unusually large purchases were observed in the changes in the positions of not only large dealers, but also of small dealers. Foreign currency buyers also bought more US dollars than usual.

#### 5.4. Liquidity dynamics

Figure 8 shows the dynamics of average market depth  $\hat{D}_{\%2}$  for the foreign exchange market, calculated in one-minute sections of the order book during trading sessions from 10:00 a.m. to 6:50 p.m. for each trading day from 13 November 2014 to 30 March 2015.

Parameter  $\hat{D}_{\%2}$  corresponds to the volume of US dollars that could be bought or sold without shifting the price more than 2% from the current market price. Its estimate is built on the basis of one-minute sections of the order book and then averaged over periods. If market depth is linearly dependent on the size of transactions, the estimate of parameter  $\hat{D}_{\%2}$  will be twice as large as the estimate of  $\hat{D}_{\%1}$ .

**Figure 8.** US dollar exchange rate and average USDRUB\_TOM market order book depth on trading days from 13 November 2014 to 30 March 2015



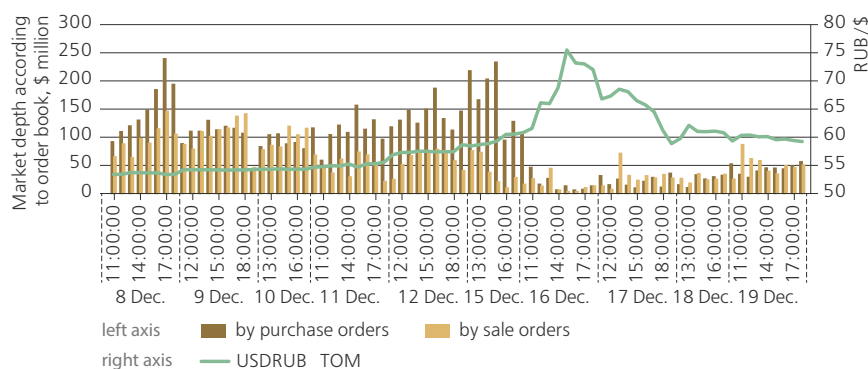
Source: authors' calculations

Estimated book depth  $\hat{D}_{\%2}$  for buy limit orders (liquidity for foreign currency sellers) is indicated in brown (left axis). Estimated book depth  $\hat{D}_{\%2}$  for sell limit orders (liquidity for buyers) is indicated in light brown (left axis). The figure also shows the dynamics of the Russian rouble exchange rate (right axis).

We can draw several conclusions. First, average market depth  $\hat{D}_{\%2}$  for the entire period from 13 November 2014 to 30 March 2015 was \$70 million, which is consistent with the  $\hat{D}_{\%1} = \$35$  million estimate in Section 3.1. Second, there was noticeable asymmetry in the order book on the side of purchases and sales of foreign currency with a predominance of buy limit orders for US dollars. That is, it was much easier to sell dollars than to buy them. This imbalance became especially noticeable starting from 11 December 2014, and on 15 December, the volume of buy limit orders for foreign currency exceeded the volume of foreign currency sell limit orders by about four times. Third, on 16 December, market depth  $\hat{D}_{\%2}$  was only \$15 million, which is about five times smaller than its average value for the entire period. It was on this day that the largest change in the exchange rate occurred.

Figure 9 shows the dynamics of liquidity calculated according to the order book for the period from 8 December to 19 December 2014 for each hour within the trading session from 10:00 a.m. to 6:50 p.m. Figure 10 shows the dynamics of liquidity in even more detail, for each minute from 10:01 a.m. to 6:49 p.m. on 15 December and 16 December 2014.

**Figure 9.** Hourly dynamics of US dollar exchange rate and average USDRUB\_TOM market order book depth on 8–19 December 2014

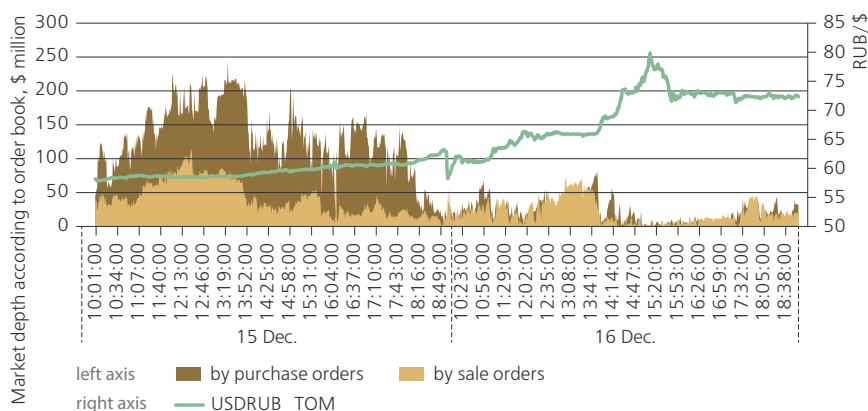


Source: authors' calculations

A few facts should be noted. First, already after lunch on 11 December 2014, a strong liquidity imbalance began to be observed in the order book, with a predominance of buy orders for US dollars. Second, by the evening of 15 December, despite large interventions by the Bank of Russia during the trading days of 12 December and 15 December, the available liquidity had decreased, and the USD/RUS exchange rate had changed from 60 roubles/dollar to almost 63 roubles/dollar, which may have coincided with the cessation of foreign exchange interventions by the regulator. Third, the increase in the key interest rate to 17% on the night of 15–16 December stopped the weakening of the Russian rouble (a temporary strengthening of the Russian rouble at the very beginning of the trading day is clearly seen in Figure 10) and restored the symmetry of the order book, but the volume of available liquidity that day remained

many times lower than usual on both the buy side and on the sell side. Fourth, the USD/RUB exchange rate increased to 80 roubles/dollar at 3:10 p.m. on Tuesday, 16 December, with an almost empty order book, and lasted only a few minutes.

**Figure 10.** Minute-by-minute dynamics of US dollar exchange rate and average USDRUB\_TOM market order book depth on 15–16 December 2014



Source: authors' calculations

Thus, our analysis shows that liquidity on the exchange was already depleted by the end of Monday, 15 December, and the depreciation of the Russian rouble to 80 roubles/dollar on Tuesday, 16 December occurred against the backdrop of an empty order book, when even small imbalances could lead to big price hikes.

Several events could have potentially led to or contributed to a liquidity crunch by the evening of 15 December.

A number of market participants were concerned that the Russian rouble exchange rate could be affected by events related to the issue of Russian rouble bonds by Rosneft. The decision on issuance was adopted by the company's board of directors on Tuesday, 9 December, orders were collected on 10 December, and information about the issue appeared on the Moscow Exchange website on 11 December at 8:00 p.m. (see Cbonds, 2014). Rosneft placed bonds with maturities of six to ten years in an amount of RUB625 billion (or approximately \$10.76 billion at a USD/RUB exchange rate of 58). The buyer of the bonds was not reported, but by Friday, 12 December, the bonds were included on the Lombard List of the Bank of Russia (Bank of Russia Bulletin, 2014).

Immediately after the announcement of the news, there were speculations that the corporation might not have had enough foreign currency liquidity to repay a \$7 billion loan taken in 2013 to buy TNK-BP with a maturity date of 22 December 2014.<sup>13</sup> It was expected that if Rosneft converted the borrowed rouble assets into foreign currency to repay the foreign currency loan, this would negatively affect

<sup>13</sup> See Temkin et al. (2015).

the Russian rouble exchange rate.<sup>14</sup> At the same time, the firm's representatives announced that they had sufficient funds to make payments on loan obligations, and the company repaid its external debt on time.<sup>15</sup>

Important events took place in mid-December 2014 in the currency derivatives market as well. On Monday, 15 December, four derivative contracts expired: SiZ4 futures contracts on the US dollar/Russian rouble currency pair and on the RTS currency index, and American cash-settled margined options on these contracts also expired. These days are sometimes referred to as the 'Days of Four Witches' and are often accompanied by increased volatility, as even small changes in the exchange rate during the expiration period can lead to notable changes in the risk profiles of option buyers and sellers and to the rebalancing of their portfolios.

At the time the derivatives expired, the total volume of open positions on call options on the exchange was approximately 1.3 million contracts, and the volume of open positions on put options was approximately 2.3 million contracts, where each contract is one \$1,000 futures contract. The put options were exercised out of the money, while many call options to buy foreign currency were unexpectedly in-the-money. The rebalancing of market participants' portfolios could have created additional imbalances in the foreign exchange market, as the sellers of call option could have sharply increased their foreign currency purchases to hedge their positions.

Additional demand for foreign currency could also have been caused by large transactions in the OTC currency derivatives market (in particular, transactions between banks and their corporate clients, which were popular at that time) due to the close relationships between all segments of the foreign exchange market. At the same time, demand for foreign currency in connection with these transactions could have arisen even if the transactions were fully hedged, such as if hedging transactions had been concluded on terms with tighter margin requirements than the underlying transactions. OTC transactions are outside the scope of our study due to a lack of data.<sup>16</sup>

In the Appendix (see the online version of this paper), we provide a detailed history of events in mid-December 2014, focusing on the period from Friday, 12 December to Tuesday, 16 December.

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<sup>14</sup> On the eve of 15 December 2014, Sergey Romanchuk expressed the opinion that, in the previous days, the entire volume of trade in the foreign exchange market was \$4–5 billion, that there was simply no one to buy \$10 billion from, except for the Bank of Russia, and that, therefore, the bond issuance was most likely conducted with the condition of not buying foreign currency with these roubles, because 'otherwise, the USD/RUB exchange rate could drop to 100 in two days'. (see Metelitsa et al., 2014).

<sup>15</sup> See Interfax (2014a).

<sup>16</sup> Additionally, on Friday, 12 December, Sberbank announced possible interruptions in the operation of cards and online services due to technical work on the night of 14–15 December. Information soon appeared in the media that users were complaining about problems with logging in and transferring money. On Tuesday, 16 December, the media published information that Sberbank had stopped lending to individuals, but the bank promptly issued a press release with a refutation. Later, head of the bank German Gref noted (see Voronova et al., 2015) that this was a critical moment for the bank's IT infrastructure, since in the same period, Sberbank had suffered an SMS attack and an X12 DDOS attack on its servers, the bank's customers were sent more than a million SMS messages about problems with the bank, and queues formed at ATMs. Since part of the withdrawn Russian rouble liquidity could have potentially been converted into foreign currency, these events could have led to additional demand for foreign currency, but their effect most likely occurred in the period after Tuesday, 16 December.

## 5.5. Actions of regulators

The Bank of Russia responded actively to the events taking place. First, on the night of 15–16 December, the Bank of Russia raised the key interest rate from 10.5% to 17%, which increased the demand for Russian roubles from market participants.

Second, the Bank of Russia carried out foreign exchange interventions, providing the market with an additional \$2.383 billion on Friday, 12 December and \$1.961 billion on Monday, 15 December. Third, the Bank of Russia carried out foreign currency repos, providing US dollar liquidity:

- 15 December: in the amount of \$1.5 billion (out of a limit of \$1.5 billion) for a period of one month with a settlement date on 17 December and \$4.829 billion (out of a limit of \$10 billion) for a term of one year with a settlement date of 17 December 2014;
- 16 December: in the amount of about \$736 million (out of a limit of \$2.0 billion) for a period of six days with a settlement date on 18 December.

These instruments most likely became US dollar liquidity bridge loans for the market, which did not have the time to ‘digest’ the large imbalances in the foreign exchange market on its own.

Taking into account its foreign exchange interventions and foreign currency repo auctions, in mid-December 2014, the Bank of Russia provided the market with about \$11 billion. The foreign exchange interventions and repo auctions proved to be effective tools that allowed the Bank of Russia to quickly add foreign exchange liquidity to the system and smooth out the imbalances.

In addition, the Russian government also requested that firms sell their foreign exchange earnings (Figure 7 shows an increase in the sale of US dollars by foreign currency sellers (exporters) on 17 December<sup>17</sup>).

The timely actions of the Bank of Russia and the government made it possible, by the end of the day on 17 December, to relieve the stress in the foreign exchange market, smooth out the resulting imbalances, and prevent panic among the population. If the actions of the regulators had been different, the force majeure in the foreign exchange market could have developed into a full-scale crisis with unforeseeable long-term consequences. At the same time, it can be assumed that the high interest rates most likely had a negative impact on the growth of the Russian economy in subsequent years.

## 6. Comparison with other crises

The Russian rouble crisis that occurred in December 2014 can be compared with other crises, many of which were caused by large imbalances that formed in the financial markets for various reasons. We compare the Russian rouble

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<sup>17</sup> According to media publications, ‘not only state-owned firms, but also large private exporters’ received ‘recommendations from the government to sell foreign currency and not make sudden rash movements in the market’ (see Koshkarov et al., 2016).

crisis with several episodes (they are analysed in more detail by Kyle and Obizhaeva, 2023).

- **1929 Crisis:** the US stock market collapsed by 25% at the end of October 1929. The main reason for the crisis was brokers' massive closure of their clients' margin positions.
- **1987 Crisis:** the US stock market fell by 32% at the end of October 1987. The main reason was that the portfolios of many pension funds had been hedged with synthetic put options, and with a small downward move in the market, this strategy involved selling index futures, which in turn led to a cascade of price drops and further selling.
- **Soros's Sales in 1987:** in late October 1987, George Soros sold futures on the US stock index, which for a while brought the market down by 22%.
- **Closing of positions by Société Générale in 2008:** For two days in January 2008, European stock markets fell 10% when the bank closed the huge speculative position of trader Jérôme Kerviel.
- **2010 Flash Crash:** In May 2010, US stock index futures collapsed by 5% in ten minutes due to forced selling of index futures by Waddell and Reed.

Table 6 presents the main parameters of the crises listed above: the actual price changes, the size of the imbalances recorded, the theoretical predictions of the price changes based on invariance theory, the value of the imbalances as a percentage of the Average Daily Volume (ADV) in the month preceding the crisis, and the Gross Domestic Product (GDP) in the year of the crisis.

For comparison, we also present the parameters of the Russian rouble crisis in December 2014, calculated based on the estimate of a \$5 billion imbalance in the Russian foreign exchange market, a \$10 billion per day average trading volume in the foreign exchange market, as well as Russia's GDP in 2014.<sup>18</sup>

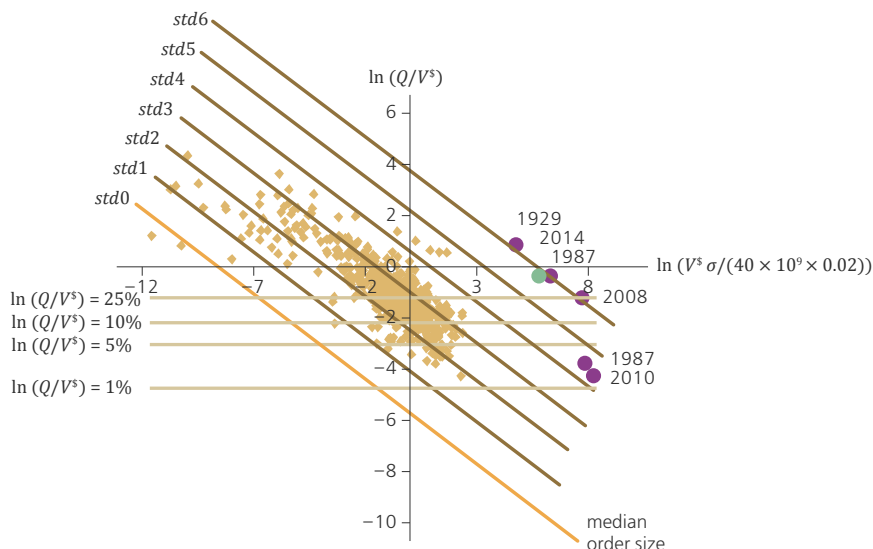
**Table 6.** Crisis parameters

	Price changes (%)		Size of imbalance		
	Actual	Theoretical	Absolute value	% ADV	% GDP
Rouble crisis in December 2014 in Russia	38	28	\$5 billion	50	0.408
1929 Crisis in USA	25	46	\$1 billion	265	1.136
1987 Crisis in USA	32	17	\$14 billion	67	0.280
Soros's sales in 1987	22	6	\$300 million	2.29	0.007
Closing of positions by Société Générale in 2008	10	11	€10 billion	28	0.401
2010 Flash Crash	5	0.61	\$4 billion	1.49	0.030

Source: Kyle and Obizhaeva (2023), authors' calculations

In Figure 11, we compare the scale of the Russian rouble crisis with the scale of past crises, adjusted for differences in liquidity between markets (this figure complements Figure 1 in the paper of Kyle and Obizhaeva, 2023).

<sup>18</sup> These calculations use the GDP first estimate of RUB71 trillion (Interfax, 2015).

**Figure 11.** Comparison of 2014 Russian rouble crisis and other crises

Note: The five violet dots represent five crises in the stock markets in the US and Europe, and the green dot corresponds to the Russian rouble crisis. The  $X$  axis represents scaled measure of market liquidity  $\ln(V^s \sigma)$ , while the  $Y$  axis represents the logarithm of sales volume  $Q/V^s$  as part of the daily trade volume. The sloped isolines correspond to imbalances ranging in size from one to six standard deviations (denoted as  $std0$  to  $std6$ ), which are equivalent after adjusting for differences in liquidity. The slope  $(-2/3)$  is based on invariance theory.

Source: authors' calculations

Even after adjusting for differences in liquidity, the 2014 Russian rouble crisis remains an extraordinary event. The size of the imbalance during this crisis was almost six standard deviations, the same as during the crises of 1929 and 1987 in the US and the collapse of European markets during the closing of speculative positions by Société Générale in January 2008.

## 7. Recommendations

In this section, we provide several recommendations that could reduce the likelihood of similar crises recurring in the future.

First, in our study, we cannot accurately determine the actual value of the imbalances during the Russian rouble crisis, since the OTC segment of the foreign exchange market remains outside the perimeter of our analysis due to a lack of data. It would be useful to organise the collection of data on exchange and OTC transactions so that data from different trading venues can be conveniently consolidated and used for analysis.<sup>19</sup>

<sup>19</sup> The problem of the non-transparency of the OTC market and the lack of statistics on it in Russia was partially resolved after the introduction of new rules for the disclosure of information on all OTC transactions under the law on the OTC foreign currency trading market of 29 December 2014 (No. 460-FZ).

Second, on the basis of such data, a system for the automatic monitoring of the positions of trading participants and of liquidity could be built, which could warn about the risks of imbalances in a timely manner.

Third, the Russian rouble crisis in December 2014 could have been partially prevented if there had been a mechanism for automatically suspending trading (circuit breaker) or slowing it down by switching to discrete auctions on the foreign exchange market of the Moscow Exchange.<sup>20</sup> In the event of significant price changes or other force majeure events, such mechanisms give traders and regulators the time to sort things out and thereby make trading systems more stable.

Mechanisms for the automatic halt of trading were first proposed in the US after the 1987 crisis and are now widely used on many trading floors. Mechanisms for slowing down trading by switching to discrete auctions began to be applied in Europe in the 1990s. Similar mechanisms were also introduced on the Moscow Exchange for the stock market in the event of a large change in the prices of particular securities or indices, but these mechanisms did not exist in the foreign exchange market at the time of the Russian rouble crisis in December 2014.<sup>21</sup>

The specific parameters of such stabilisation mechanisms (for example, conditions for a halt to trading, the duration of the pause, and the characteristics of the discrete auctions) should be selected based on the particularities of each market. Incorrectly chosen parameters could lead to unsuccessful results. For example, when the trading halt mechanism was introduced in China in 2016, the halt thresholds were set too strictly, resulting in the mechanism being triggered too frequently and subsequently cancelled. A number of design issues for this mechanism are discussed by the Securities and Futures Commission (2001) and the World Federation of Exchanges (2008). Given the existence of an active OTC foreign exchange market, we recommend slowdowns to on-exchange trading in the foreign exchange market for short periods of time, such as, for example, no more than 15 minutes.<sup>22</sup>

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<sup>20</sup> According to the Moscow Exchange rules for exchange trading that were in force in 2014 in the foreign exchange and precious metals markets, the exchange could change price ranges and collateral rates, but these measures had only a limited effect. The Moscow Exchange's foreign exchange market did not provide for a procedure for the automatic suspension of trading in the event of significant exchange rate fluctuations. Only the Bank of Russia had the authority to halt trading, but a halt could occur only in certain cases, which did not include significant changes in the exchange rate. According to the rules, it was possible to halt or terminate on-exchange trading 'in the event of circumstances that interfere with or may interfere with the ordinary course of trading, which, in particular, include: technical failures in the operation of trading tools (including failures in the operation of software); attempts at unauthorised access to the tools for trading; failures in the operation of communication systems or the power supply; force majeure circumstances; improper functioning of the Clearing Centre and/or other organisations whose activities affect the possibility of trading'.

<sup>21</sup> The procedure for trading in the form of discrete auctions on the Moscow Exchange is available at: <https://www.moex.com/a775>

<sup>22</sup> A halt in trading for a short time is an effective measure in the event of technical failures, errors in trading algorithms, and other non-critical technical issues. In more difficult situations (for example, the collapse of the banking system or the disruption of infrastructure due to terrorist attacks), on-exchange trading should be halted for a longer period of time.

One of the main arguments against the introduction of a mechanism to slow down or halt trading in the Russian foreign exchange market is the fear that if trading is halted on the main trading floor, traders will switch to the OTC market en masse.

We believe that a halt or slowdown in trading on the Moscow Exchange for a short period in the event of a sharp change in the exchange rate will lead to less reputational risk than the possible alternatives. Traders who actually switch to the OTC market during a slowdown in exchange trading are likely to face large spreads in prices in this market, randomness of transactions, an increased risk of errors, and the likely cancellation or revision of transactions, which, in particular, will create risks in cross-market arbitrage, so these traders are likely to have a negative experience with the OTC markets. If traders remain on the Moscow Exchange, they will have the time to sort the situation out and continue trading in a regularly operating market within a few minutes, avoiding the potential risks of off-market transactions, technical failures, and other troubles.

*Appendix is available at*  
**<https://rjmf.econs.online>**

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\* The Ministry of Justice of Russian Federation included Sergey Guriev in the registry of foreign agents.

## APPENDIX

# The Russian Rouble Crisis of December 2014: Structure and Liquidity of a Foreign Exchange Market

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### History of events

In the Appendix, we provide a brief history of events in November–December 2014, focusing on the period from Friday, 12 December to Tuesday, 16 December:

10 November 2014: The Bank of Russia completed the transition to a floating Russian rouble exchange rate.

27 November 2014: OPEC refused to cut oil production. Oil prices fell by 5%. The USD/RUB exchange rate rose to a historic high of 54 roubles/dollar.

1 December 2014 to 11 December 2014: The Bank of Russia's interventions amounted to about \$6 billion<sup>1</sup>.

9 December 2014: The Board of Directors of Rosneft adopted a resolution to issue bonds.

10 December 2014: Through the mediation of the Russian Regional Development Bank (RRDB), controlled by Rosneft, applications for the purchase of Rosneft bonds were collected from 5:00 p.m. to 6:00 p.m.

11 December 2014: The Bank of Russia raised the key interest rate from 9.5% to 10.5%.

11 December 2014: Rosneft issued bonds in the amount of RUB625 billion. Information about the issue appeared on the Moscow Exchange website at 8:00 p.m.

12 December 2014: The Bank of Russia's interventions amounted to about \$2.383 billion.

15 December 2014: The Bank of Russia provided liquidity in US dollars through foreign currency repos: \$1.5 billion (out of a limit of \$1.5 billion) for a period of one month, with the settlement date for the first part on 17 December, and \$4.829 billion (out of a limit of \$10 billion) for a period of one year, with the settlement date of the first part on 17 December 2014.<sup>2</sup> Participants in the auctions could transfer to the Bank of Russia as collateral 151 Eurobonds, as well as other securities included on the Bank of Russia's Lombard List, in particular, bonds of Rosneft, which had been included on the list shortly before (see Moscow Exchange, 2014).<sup>3</sup>

15 December 2014: Representatives of Rosneft announced the availability of funds sufficient to make payments on loan obligations.<sup>4</sup>

15 December 2014: SiZ4 futures contracts<sup>5</sup> on the US dollar-Russian rouble currency pair and on the RTS currency index expired, and American cash-settled margined options on these contracts also expired.<sup>6</sup>

15 December 2014: the Bank of Russia stopped interventions in the evening. By the end of the trading day, the USD/RUB exchange rate reached the level of 64 roubles/dollar.

<sup>1</sup> On 8, 9, 10, and 11 December, foreign currency sales amounted to: \$400 million, \$348 million, \$206 million, and \$478 million, respectively. On Friday, 5 December, foreign exchange sales amounted to \$1.926 billion.

<sup>2</sup> The Bank of Russia held its first annual foreign exchange repo auction on 17 November 2014, at which banks took only \$87 million of the \$10 billion offered.

<sup>3</sup> On 15 December 2014, the Bank of Russia also held a Lombard credit auction to provide loans at a floating interest rate for a period of 36 months (the date of the Bank of Russia loans was 16 December 2014). The maximum amount of funds provided was RUB700 billion, and the auction was declared invalid due to a lack of orders.

<sup>4</sup> On 15 December 2014: Representatives of Rosneft stated that 'the firm generates sufficient cash flow in foreign currency to make the current payments on its loan obligations. Rouble bonded loans are raised exclusively to finance projects in Russia. Until the need for settlements in the implementation of the company's investment projects in the current and subsequent years, all Russian rouble assets will be held in Russian rouble deposits at authorised banks. The use of these funds for the purchase of foreign currency is not provided for either by the loan agreements or by the company's plans. Thus, not a single rouble attracted under the bond placement programme will be used to purchase foreign currency' (Interfax, 2014).

<sup>5</sup> The execution price of the SiZ4 futures was calculated based on the average prices of transactions and orders calculated per second for the period from 12:25:01 to 12:30:00 (Moscow time), inclusive.

<sup>6</sup> The change in the exchange rate led to a drop in futures prices for the RTS index as calculated in US dollars. On 15 December, for the first time, the Bank of Russia instructed the Moscow Exchange to halt trading in shares 'in order to prevent possible manipulation' during the expiration of futures contracts for the RTS index for the period from 3:00 p.m. to 4:00 p.m., during which period the expiration price of futures contracts was calculated, for certain broker clients (see Bank of Russia, 2014).

16 December 2014: On the night of 16 December, the Bank of Russia raised the key interest rate from 10.5% to 17%.

16 December 2014: Trading opened with a sharp drop in the USD/RUB exchange rate to 58 roubles/dollar. The exchange rate then began to grow, and by 1 p.m., almost all the blotters (except for the most liquid instruments) on the Moscow Exchange foreign currency market were empty.

16 December 2014: SMS attacks on Sberbank occurred.

16 December 2014: The government recommended that state-owned firms and large exporters sell foreign currency and not make sudden, thoughtless movements.

16 December 2014: At 3:10 p.m., the USD/RUB exchange rate reached a historical maximum of 80 roubles/dollar.

16 December 2014: At 3:48 p.m., the Bank of Russia conducted a foreign exchange repo transaction in the amount of about \$736 million (out of a limit of \$2.0 billion) for a period of six days, with the settlement date for the first part on 18 December.

16 December 2014: At 4:00 p.m., the USD/RUB exchange rate dropped to 72 roubles/dollar.

17 December 2014: The USD/RUB exchange rate fell below 60 roubles/dollar by the evening of the trading day.

22 December 2014: Rosneft announced the payment of about \$7 billion to a group of its creditors and the repayment of part of the loans raised to finance the acquisition of TNK-BP in 2013.

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