MEĐUZAVISNOST VOLATILNOSTI CENE NAFTE I DEVIZNOG KURSA RUBLJE TOKOM KRIZE U UKRAJINI

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doi: 10.59864/Oditor12402B

Originalni naučni rad
UDK: 336.74
339.13.025:327.5(477)"2022"

Apstrakt

Predmet istraživanja ovog rada je uticaj krize u Ukrajini na volatilnost rublje i nafte, kao i korelacija ovih vrednosti međusobno. Kako bi istražili uticaj krize u Ukrajini, kao eksternog šoka na volatilnost rublje i sirove nafte analizirane su promene odnosa njihovih vrednosti na dnevnom nivou, u posmatranom periodu tokom 2022. godine i prva četiri meseca 2023. godine. Analizom vremenskih serija, a potom i komparativnom analizom navednih podataka i korišćenjem GARCH modela utvrđena je određena divergentnost u samoj prirodi ponašanja i kretanja rublje i nafte neposredno pre početka i tokom trajanja krize u Ukrajini, u toku posmatranog perioda. Nema sumnje da su se tržišta ruske valute i sirove nafte u ovom periodu ponašala mnogo volatilnije, što implicira i značajno veći uticaj na ekonomske aktivnosti, imajući u vidu nestabilnost vrednosti rublje i nafte kao značajnih činilaca uticaja na ukupna ekonomska kretanja u svetu.

Ključne reči: *rublja, sirova nafta, komparativna analiza, GARCH, korelacija*

JEL: *C58 G15 M24*

Uvod

Predmet ovog istraživanja su vrednosti valutnog para RUB/EUR i sirove nafte kao robe koja u značajnoj meri utiče na vrednost valuta i ostalih roba, odnosno analiza uticaja krize u Ukrajini na volatilnost rublje i cene sirove nafte. Istraživanje je sprovedeno u kontekstu analize promene vrednosti ruske rublje i nafte u periodu od 01.01.2022. do 30.04.2023. Centralni problem koji se razmatra je volatilnost vrednosti rublje i nafte pod uticajem aktuelne krize u Ukrajini, te njihova korelacija u navedenom periodu. Obzirom da su pomenuta politička i ekonomska dešavanja značajno uticala na vrednost posmatranih varijabli, primarni cilj ovog istraživanja je dobijanje odgovora na pitanje kolike i kakve su po prirodi promene

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vrednosti rublje i nafte i priroda njihovog međusobnog odnosa u posmatranom periodu. Shodno tome zadaci istraživanja su:

- utvrđivanje promena vrednosti valutnog para RUB/EUR i odnosa OIL/EUR pod uticajem krize u Ukrajini u periodu od šesnaest meseci;
- upoređivanje odnosno komparacija vrednosti rublje i nafte u odnosu na evro u navedenom periodu;
- izračunavanje i obrazloženje vrednosti korelacione matrice odnosno koeficijenta korelacije *r* između uslovnih varijansi varijabli: RUB/EUR i OIL/EUR, dobijenih korišćenjem GARCH modela.

Polazna hipoteza koja je testirana u istraživanju glasi: ruska rublja i nafta su se tokom krize u Ukrajini, u posmatranom periodu, pokazale kao vrednosti koje su umereno međusobno povezane. Kroz vremenske serije dnevnih podataka upoređene su vrednosti rublje i nafte u odnosu na evro, i uočene su sličnosti i razlike. Obe posmatrane serije podataka predstavljene su odvojeno, zbog tačnijeg prikaza rezultata analize.

Rezultati istraživanja su prezentovani deskriptivno, zatim kroz nekoliko tabela i grafikona sa uporednim rezultatima. Korišćenjem GARCH modela ocenjena je volatlnost posmatranih varijabli i na kraju je izračunata njihova korelacija.

Pregled literature

Devizni kursevi većine privredno razvijenih zemalja sveta svakodnevno više ili manje osciliraju, a posebno su interesantni dugoročni trendovi, važni prilikom ugovaranja dugoročnih komercijalnih i finansijskih poslova (Obradović et al., 2018). Volatilnost predstavlja raspon i brzinu kretanja cena i kao takva daje mogućnost merenja rizika određenih ekonomskih parametara. Kod kretanja vrednosti valutnog para RUB/EUR imamo volatilnija kretanja, i to iz vrlo logičnog i poznatog razloga. Pre svega, kriza u Ukrajini je direktno vezana za involviranost Rusije i u političkom i u ekonomskom pogledu. Početkom ukrajinske krize, došlo je do povećanja cena energenata, a samim tim i stope inflacije gotovo u svim državama sveta, te bi pažnju trebalo obratiti na agilne metode upravljanja u cilju prilagođavanja promenljivim uslovima na tržištu (Balaban, Đurašković, 2021).

Očigledno je da su porast cena energenata i hrane na svetskim tržištima od početka ukrajinske krize, snažno uticali na jačanje rublje kao valute jedne od država sa najvećim učešćem u proizvodnji i izvozu energenata i hrane na svetu. Rusija proizvodi oko 18% non-OPEC proizvodnje i 12% ukupne svetske proizvodnje u 2021. godini (Onour, Abdo, 2022).

Kako bi što studioznije ispitali uticaj krize u Ukrajini na promene vrednosti rublje i nafte, izvršićemo analizu volatilnosti ovih vrednosti u posmatranom periodu.

Ovo iz razloga što jedna od osnovnih karakteristika plivajućih deviznih kurseva jeste visoka volatilnost koja se ispoljava na nekoliko načina (Balaban, 2019), i pomoću nje možemo na kvalitetan način meriti promene navedenih vrednosti. U poslednjih nekoliko decenija, pogotovu posle kolapsa Breton-Vudskog sporazuma o fiksnim kursevima, volatilnost deviznih kurseva je dobila posebnu pažnju kod makroekonomske analize, obzirom da pod uticajem globalizacije svetske ekonomije utiče na brojne makroekonomske faktore.

Sa druge strane, cene nafte i devizni kursevi su povezani sa ekonomijom. Zapravo, obe ove serije podataka pomno prate učesnici na finansijskim tržištima i kreatori politika. U literaturi postoje različiti teorijski modeli koji povezuju cene nafte i devizne kurseve. Seminarski radovi Krugmana i Goluba, oba napisana 1983. godine, pružaju teorijske modele koji čine temelj mnogih empirijskih rezultata (Anjum, 2019). Oni tvrde da zemlje izvoznice nafte imaju povećanje bogatstva u kratkom roku kada cene nafte rastu, što dovodi do poboljšanja bilansa tekućeg računa, odnosno apresijacije deviznog kursa valute zemlje izvoznice nafte.

Analiza promene apsolutnih vrednosti RUB/EUR i OIL/EUR

U cilju poređenja vrednosti ruske rublje sa naftom kao robom široke potrošnje na globalnom tržištu analizirane su vremenske serije podataka za rusku rublju i vrednosti barela nafte u odnosu na evro tokom posmatranog perioda,

Analizom grafika 1, uočava se nekoliko ključnih tačaka dnevnih preseka. Upravo te ključne tačke razlikuju kretanje vrednosti ruske rublje prema evru u odnosu na bilo koju drugu nacionalnu valutu čije bi kretanje vrednosti posmatrali u analiziranom periodu. Minimalna vrednost valutnog para RUB/EUR u posmatranom periodu bila je 07. marta odnosno 09. marta 2022. godine i iznosila je 0,0065 evra za jednu rublju. Kao što možemo videti, odmah nakon početka krize u Ukrajini, vrednost ovog valutnog para je oslabila sa 0,0109 evra za jednu rublju na zatvaranju 23. februara 2022. godine na 0,0065 evra za jednu rublju, na zatvaranju tržišta 07. marta 2022. godine, što je pad rublje od 40,37% u prvih dvanaest dana od početka rata u Ukrajini.

Međutim, vlasti Ruske federacije donose odluku o pegovanju vrednosti rublje za vrednost unce zlata, a krajem marta i odluku o prodaji energenata: gasa i nafte isključivo u rubljama, definisanu po unapred određenoj šemi za plaćanje (Pavićević, 2022). Takve ekonomsko-političke odluke ruskih vlasti su dovele do gotovo konstantnog rasta rublje u odnosu na evro od tih događaja. Tako već 31. marta 2022. godine, kad se već znalo da će Rusija energente prodavati samo za sopstvenu valutu, odnos valutnog para RUB/EUR je bio blizu onoga sa početka ukrajinske krize i iznosio je 0,011 evra za 1 rublju. Trend je nastavljen i tokom aprila, maja i juna meseca, pa maksimalnu vrednost valutnog para RUB/EUR imamo 29. juna, kada vrednost iznosi 0,0182 evra za jednu rublju, što je

povećanje od 180,00% u odnosu na minimalnu vrednost od 07. marta i 09. marta 2022. godine, tek petnaestak dana od početka krize u Ukrajini.

Grafik 1. Kretanje vrednosti rublje u periodu od 01.01.2022. do 30.04.2023.

Izvor: kalkulacija autora na osnovu podataka dostupnih na https://exchangerates.org.uk/

Poput analize promene vrednosti ruske nacionalne valute u datom periodu, i za potrebe ove analize za referentnu vrednost uzet je evro, kako bi komparativna analiza što kvalitativnije odslikavala odnos izabranih varijabli. Iako se cena nafte na berzama izražava u dolarima, ovde je kao odgovarajući paritet uzet odnos OIL/EUR.

Na osnovu analize Grafika 2 uočava se uvećana volatilnost tržišta kod naftnog tržišta, nego li je to obično slučaj kod volatilnosti nacionalnih valuta. Ako pogledamo minimalnu i maksimalnu vrednost nafte na dnevnom nivou na zatvaranju tržišta, izraženu u evrima u posmatranom periodu, uočićemo koliko su procentualno iznosile promene vrednosti nafte. Jedna od minimalnih vrednosti nafte u posmatranom periodu bila je 66,42371 EUR, 01. januara 2022. godine, a maksimalna vrednost u istom posmatranom periodu iznosila je 116,70415 EUR, na dan 06. mart 2022. godine, desetak dana nakon početka ratne krize u Ukrajini. Dakle, maksimalna vrednost nafte je bila veća od njene minimalne vrednosti za 75,70%.

Grafik 2. Kretanje vrednosti barela nafte u periodu od 01.01.2022. do 30.04.2023.

Izvor: kalkulacija autora na osnovu podataka dostupnih na https://exchangerates.org.uk/

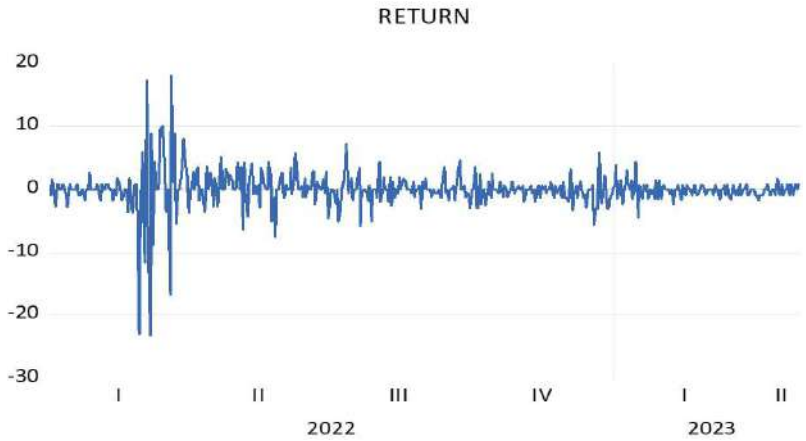
Treba imati u vidu da je nakon pika na grafiku, vrednost nafte, uz manje oscilacije, uglavnom opadala, što znači da je nagli porast cene u roku od oko dva meseca, dominantno bio špekulativnog karaktera. Tome, ide u prilog činjenica, da je dana 18. marta 2023. godine, dok još traje kriza Ukrajini, vrednost nafte iznosila 61,71406 EUR, što je manje od vrednosti na početku 2022. godine. Volatilnost nafte kao mera rizika, ovim odnosom pokazuje veći rizik od investiranja u naftu.

Volatilnost valutnog para RUB/EUR tokom krize u Ukrajini

Analiza volatilnosti valutnog para RUB/EUR pre i tokom još aktuelne krize u Ukrajini, je podrazumevala analizu 485 podataka, tačnije logaritmovanih dnevnih stopa prinosa valutnog para RUB/EUR u periodu od šesnaest meseci. Autori su u prvom koraku analizirali grupisanje volatilnosti pomenute vremenske serije.

Grafik 3 jasno pokazuje da postoji grupisanje volatilnosti stopa prinosa valutnog para RUB/EUR. Kako su ekstremne vrednosti vremenske serije valutnog para RUB/EUR uočljive u I kvartalu 2022. godine, i grupisanje volatilnosti vremenske serije logaritmovanih dnevnih stopa prinosa valutnog para RUB/EUR pokazuje identičan slučaj, što je rezultat početka ratne krize u Ukrajini.

Grafik 3. Grupisanje volatilnosti – valutni par RUB/EUR



Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

U drugom koraku autori uz pomoć Bai-Perron testa ocenjuju da li je poznati egzogeni događaj, početak krize u Ukrajini, delovao na pojavu strukturnog loma u posmatranoj vremenskoj seriji podataka. Na osnovu rezultata testa zaključujemo da kod posmatrane vremenske serije nema strukturnog loma *(Tabela 1)*.

Tabela 1. Rezultat Bai-Perron testa – valutni par RUB/EUR

Bai-Perron test of L+1 vs. L sequentially determined breaks **Uključeno 484 uzorka**			
Sequential F-statistic determineted breaks: 0			
Break test	F-statistic	Scaled F-statistic	Critical Value
0 vs. 1	1.677169	1.677169	8.58
Significant at the 0,05 level.			

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Primenom ADF i KPSS testova jediničnog korena ocenjena je stacionarnost posmatrane vremenske serije. ADF test polazi od H_0 da posmatrana serija ima jedan jedinični koren, i u tom slučaju nije stacionarna. Obzirom da je vrednost verovatnoće $p<0,05$ u oba slučaja, posmatrana serija nema jedinični koren *(Tabela 2)*, odnosno stacionirana je, što je od temeljne važnosti za nastavak istraživanja.

Tabela 2. Rezultati ADF testa – valutni par RUB/EUR

Exogenous: Constant		
	t-statistic	Prob.*

Augmented Dickey-Fuller test statistic	-24.96920	0.0000
Exogenous: Constant, Linear Trend		
Augmented Dickey-Fuller test statistic	-24.98543	0.0000

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

U cilju provere dobijenih rezultata primenjen je KPSS test koji polazi od hipoteze H_0 da je posmatrana vremenska serija stacionarna. Stacionarnost posmatrane vremenske serije potvrđuje i rezultat KPSS testa obzirom da je p>0,05 u oba slučaja *(Tabela 3)*.

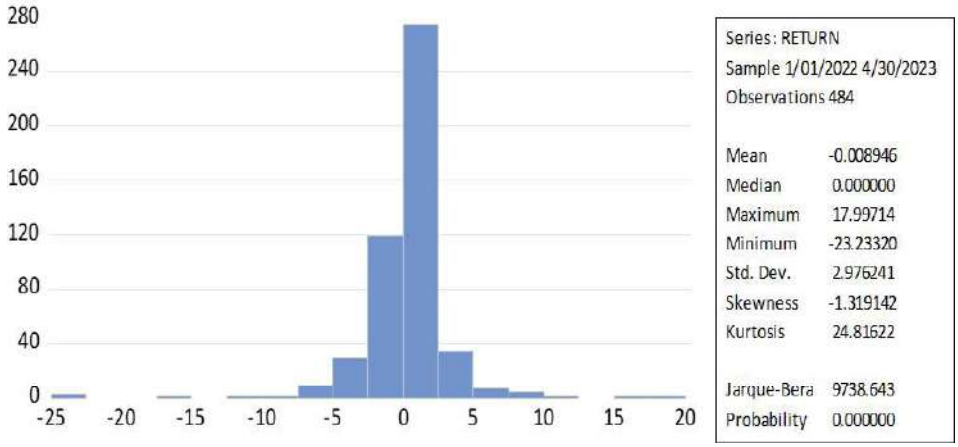
Tabela 3. Rezultat KPSS testa – valutni par RUB/EUR

Exogenous: Constant	
	LM-Stat.
Kwiatkowski-Philips-Scmidt-Shin test statistic	0.166746
Exogenous: Constant, Linear Trend	
Kwiatkowski-Philips-Scmidt-Shin test statistic	0.068106

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Za detaljniju analizu posmatrane vremenske serije korišlena je deskriptivna statistika (Grafik 4). Na osnovu dobijenih rezultata Jarque-Bera testa može se zaključiti da posmatrana vremenska serija nema normalnu distribuciju, što je i uočljivo na Quantile-Quantile (QQ) histogramu (Grafik 5). Koeficijent asimetrije je manji od 0 što znači da posmatrana vremenska serija ima negativnu asimetriju, dok koeficijent spljoštenosti iznad 3 pokazuje da je posmatrana serija podataka izdužena. Vrednost koeficijenta asimetrije je negativna: -3,817822, što pokazuje da se radi o izraženoj negativnoj asimetriji. Koeficijent spljošenosti sa iznosom od 47,59308 apsolutno odgovara izduženosti koja je prikazana na histogramu (Grafik 4.) i koja je značajno veća od one koja je karakteristična za normalnu distribuciju.

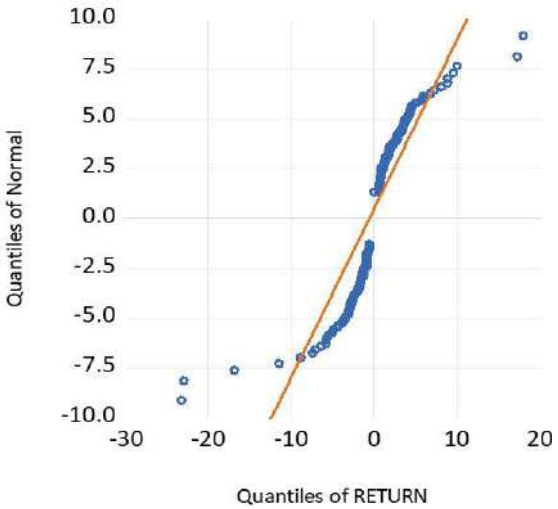
Grafik 4. Deskriptivna statistika – valutni par RUB/EUR



Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Kao što je već navedeno, nalaz da posmatrana serija podataka nema normalnu distribuciju potvrđen je i sledećim grafikom:

Grafik 5. QQ histogram – valutni par RUB/EUR



Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

U daljem radu autori istražuju autokorelaciju u podacima posmatrane vremenske serije. Kada je u pitanju autokorelacija i u ovom analiziranom slučaju poći će se od hipoteze H_0 da u posmatranoj vremenskoj seriji podataka ne postoji autokorelacija.

Tabela 4. Rezultati testa za detektovanje autokorelacije – valutni par RUB/EUR

Q	AC	PAC	Q-Stat	Prob
(1)	0,003	0,003	0,0032	
(10)	-0,052	-0,092	31,828	0,0000
(20)	0,046	-0,007	59,701	0,0000
(30)	-0,027	-0,004	69,038	0,0000

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Posmatrajući dobijene rezultate o autokorelaciji, parcijalnoj korelaciji, te Q-statistici i verovatnoći, a prateći verovatnoću na Q (10), Q (20) i Q (30), vrlo jednostavno se može primetiti da je u svim slučajevima $p<0,05$, što znači da polazna hipoteza nije potvrđena i da autokorelacija postoji. Shodno tome, utvrđena je adekvatna ARMA specifikacija na bazi najniže vrednosti Schwarz criterion (SIC) - MA (1) kako bi se otklonila autokorelacija i sproveo test heteroskedastičnosti.

Heteroskedastičnost pokazuje činjenicu da je varijansa neke slučajne greške različita za različite vrednosti određene nezavisne promenljive, odnosno da ne prati konstantnu vrednost. U tom smislu autori ispituju da li postoji ARCH efekat, kako bi videli da li se javlja heteroskedastičnost, što je veoma važno sa aspekta nastavka istraživanja.

Tabela 5. Rezultati ARCH testa – valutni par RUB/EUR

Heteroskedasticity Test: ARCH			
F-statistic	19,46771	Prob. F (1,481)	0,0000
Obs*R-Squared	18,78823	Prob. Chi-Square (1)	0,0000

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Na osnovu rezultata *(Tabela 5)* može se uočiti da postoji ARCH efekat, odnosno da je $p<0,05$. Korišćenjem najnižeg SICa izabran je odgovarajući GARCH model, što je u ovom slučaju FIGARCH (1,1).

Kako bi se utvrdilo da li postoji značajna autokorelacija u rezidualima, prikazane su vrednosti Q (1), Q (10), Q (20) i Q (30) na korelogramu reziduala. U slučaju da te vrednosti u više slučajeva iznose $p>0,05$, onda bi mogli zaključiti da je posmatrani model dobar i da nema značajne autokorelacije u rezidualima. Nakon što je utvrđeno da li ima autokorelacije u rezidualima, ispitano je da li je prisutan ARCH efekat u rezidualima posmatrane serije podataka.

Tabela 6. Korelogram standardizovanih reziduala – stopa povrata RUB/EUR

Q	AC	PAC	Q-Stat	Prob*
(1)	-0,008	-0,008	0,0346	0,853
(10)	-0,006	-0,005	5,9895	0,816
(20)	0,029	0,030	6,8213	0,997
(30)	-0,012	-0,010	7,2056	1,000

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Na osnovu posmatranih vrednosti verovatnoće u uzorku možemo zaključiti da je model dobar i da nema značajne autokorelacije u rezidualima posmatrane serije podataka *(Tabela 6)*.

Na osnovu tabele koja sledi *(Tabela 7)* može se na osnovu dobijene verovatnoće zaključiti da ne postoji ARCH efekat u rezidualima posmatrane vremenske serije podataka, odnosno da je odgovarajući model adekvatno specifikovan.

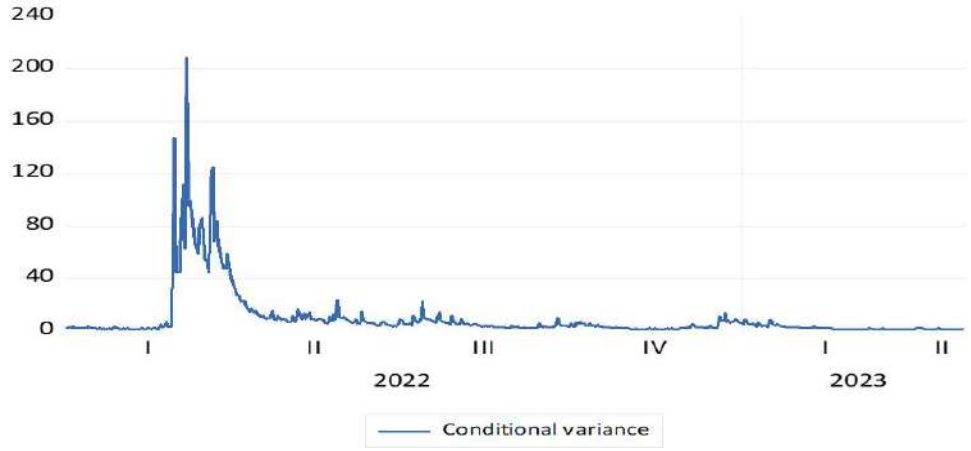
Tabela 7. Testiranje ARCH efekta u rezidualima – valutni par RUB/EUR

Heteroskedasticity Test: ARCH			
F-statistic	0,034141	Prob. F (1,481)	0,8535
Obs*R-Squared	0,034281	Prob. Chi-Square (1)	0,8531

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Na grafiku 6 prikazana je uslovna varijansa derivirana iz FIGARCH (1,1) modela koja prikazuje volatilnost vremenske serije logaritmovanih dnevnih stopa prinosa valutnog para RUB/EUR, što je uslov za izračunavanje korelacije između volatilnosti ruske rublje i volatilnosti cena nafte, a što je predmet istraživanja rada.

Grafik 6. Uslovna varijansa derivirana iz FIGARCH (1,1) modela - par RUB/EUR



Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Volatilnost cene nafte tokom krize u Ukrajini

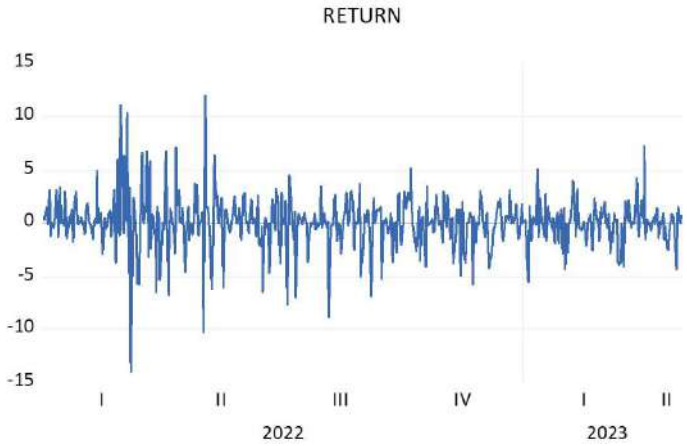
Analiza promene vrednosti sirove nafte izražene u eurima OIL/EUR, pre i tokom aktuelne krize u Ukrajini, podrazumeva logaritmovanu dnevnu stopu prinosa. U skladu sa tim, analiziran je uzorak od 485 podataka. Kao jedna od karakteristika, analizirano je grupisanje volatilnosti vremenske serije logaritmovanih dnevnih stopa vrednosti nafte izražene u eurima, što nije uobičajeno, kako bi taj odnos mogao da se adekvatno uporedi sa valutnim parom RUB/EUR.

Kao što se vidi na grafiku 7, kod malih promena vrednosti stopa prinosa uočavaju se male promene vrednosti posmatrane serije OIL/EUR, dok kod većih promena vrednosti stopa prinosa date vremenske serije imamo velike promene posmatrane serije vrednosti OIL/EUR. Takođe, ekstremne vrednosti vremenske serije OIL/EUR uočavaju se u I i II kvartalu 2022., što je pokazalo i grupisanje volatilnosti vremenske serije logaritmovanih dnevnih stopa prinosa vrednosti sirove nafte, što je posledica započete ratne krize u Ukrajini.

Uz pomoć testa strukturnih lomova, korišćenjem Bai-Perron procedure ispitano je da li je posmatrani egzogeni događaj, odnosno početak ratne krize u Ukrajini, delovao na pojavu strukturnog loma u posmatranoj vremenskoj seriji podataka. Na osnovu rezultata testa *(Tabela 8)* zaključeno je da kod posmatrane vremenske serije podataka nema definisanih strukturnih lomova, izazvanih egzogenim događajem, odnosno u ovom slučaju početkom krize u Ukrajini.

Evo grafičkog prikaza grupisanja volatilnosti za OIL/EUR:

Grafik 7. Grupisanje volatilnosti – OIL/EUR



Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Kako je prethodno navedeno, sledi test strukturnih lomova, korišćenjem Bai-Perron procedure:

Tabela 8. Rezultat Bai-Perron testa – OIL/EUR

Bai-Perron test of L+1 vs. L sequentially determined breaks **Uključeno 484 podatka**			
Sequential F-statistic determineted breaks: 0			
Break test	F-statistic	Scaled F-statistic	Critical Value
0 vs. 1	1.677169	1.677169	8.58
Significant at the 0,05 level.			

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Kao i u prethodnom slučaju, primenom ADF i KPSS testova jediničnog korena autori proveravaju da li je posmatrana vremenska serija podataka stacionarna.

Na osnovu dobijenih rezultata ADF testa *(Tabela 9)* možemo zaključiti da je posmatrana serija logaritmovanih dnevnih stopa prinosa vrednosti OIL/EUR stacionarna.

Tabela 9. Rezultati ADF testa – OIL/EUR

Exogenous: Constant		
	t-statistic	Prob.*
Augmented Dickey-Fuller test statistic	-22.29421	0.0000
Exogenous: Constant, Linear Trend		
Augmented Dickey-Fuller test statistic	-22.35367	0.0000

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Na osnovu dobijenih rezultata KPSS testa može se, kao i kod prethodne primene ADF testa, zaključiti da je posmatrana vremenska serija podataka stacionirana *(Tabela 10)*.

Tabela 10. Rezultati KPSS testa – OIL/EUR

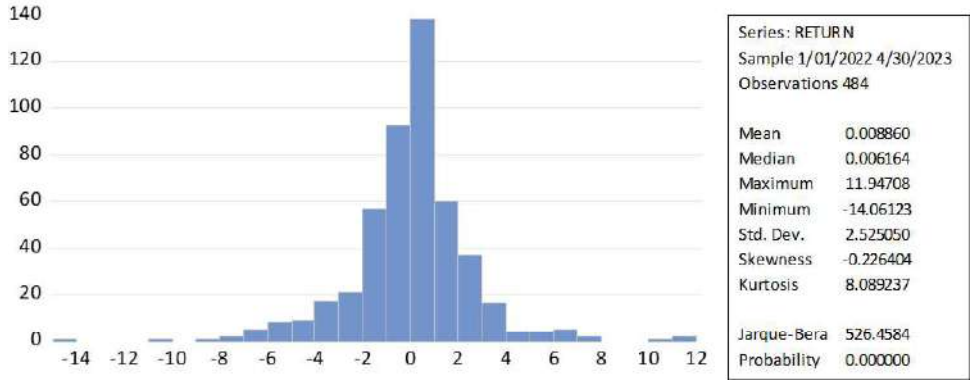
Exogenous: Constant	
	LM-Stat.
Kwiatkowski-Philips-Scmidt-Shin test statistic	0.242345
Exogenous: Constant, Linear Trend	
Kwiatkowski-Philips-Scmidt-Shin test statistic	0.065226

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

U cilju što boljeg opisa podataka posmatrane vremenske serije, predstavljena je deskriptivna statistika. Putem Jarque-Bera statistike testira se normalnost distribucije.

Na osnovu dobijenih rezultata (Grafik 8) može se videti da je vrednost $p<0,05$, što implicira da posmatrana serija podataka OIL/EUR nema normalnu distribuciju i da značajno odstupa od srednje vrednosti, što potvrđuje i QQ histogram (Grafik 9). Koeficijent asimetrije iznosi -0,226404, te posmatranu vremensku seriju podataka karakteriše negativna asimetrija, dok prema istoj tabeli koeficijent spljoštenosti iznosi 8,089237. Ovoliki njegov iznos znači da je posmatrana serija podataka izdužena, jer je koeficijent spljoštenosti znatno veći od 3.

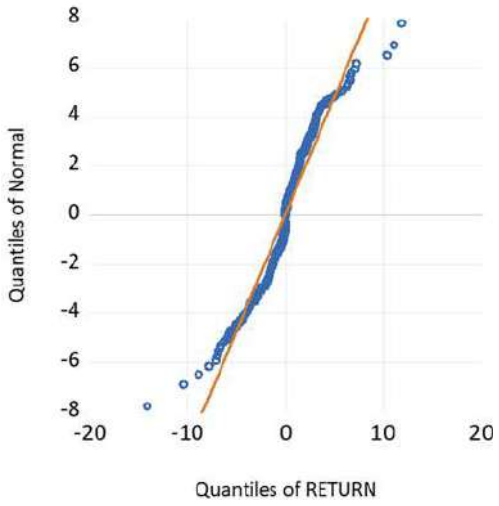
Grafik 8. Deskriptivna statistika – OIL/EUR



Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Sledi i QQ histogram, koji potvrđuje da nema normalne distribucije.

Grafik 9. QQ histogram – OIL/EUR



Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Kada je u pitanju autokorelacija i u ovom slučaju se polazi od hipoteze H_0: u posmatranoj vremenskoj seriji reziduala ne postoji korelacija. Na osnovu dobijenih podataka o autokrelaciji, parcijalnoj korelaciji, Q statistici i verovatnoći, a prateći verovatnoću na Q(1), Q(10), Q(20) i Q(30) uzorku, vrlo jednostavno se može primetiti da je u svim posmatranim slučajevima $p>0,05$, što znači da je polazna hipoteza potvrđena i da nema autokorelacije u posmatranoj vremenskoj seriji podataka *(Tabela 11)*. Primenom LM testa serijske korelacije dobijen je isti rezultat *(Tabela 12)*. Može se tvrditi da ne postoji autokorelacija u posmatranoj vremenskoj seriji podataka obzirom da je verovatnoća $p>0,05$.

Tabela 11. Rezultati testa za detektovanje autokorelacije – OIL/EUR

Q	AC	PAC	Q-Stat	Prob
(1)	-0,0016	-0,0016	0,1321	0,716
(10)	-0,021	-0,014	9,7774	0,460
(20)	0,034	-0,033	25,576	0,180
(30)	-0,002	-0,033	40,034	0,104

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Tabela 12. Rezultati LM testa za detektovanje autokorelacije – OIL/EUR

Breusch-Godfrey Serial Corellation LM Test **H0: No serial correlation at up to 2 lags**			
F-Statistic	0,225217	Prob. F (2,481)	0,7984
Obs*R-Squared	0,452819	Prob. Chi-Square (2)	0,7974

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Sledeći korak koji se sprovodi je testiranje heteroskedastičnosti. Na osnovu dobijenih rezultata *(Tabela 13)* možemo uočiti da postoji ARCH efekat, budući da je $p<0,05$.

Tabela 13. Rezultati ARCH testa – OIL/EUR

Heteroskedasticity Test: ARCH			
F-statistic	5,499866	Prob. F (1,481)	0,0194
Obs*R-Squared	5,460300	Prob. Chi-Square (1)	0,0195

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Na osnovu izračunate vrednosti najnižeg SIC kriterijuma izabran je GARCH (1,1) model. U cilju utvrđivanja adekvatnosti izabranog modela, testirano je postojanje autokorelacije i heteroskedastičnosti u rezidualima ocenjenog modela. Na bazi posmatranih vrednosti zaključujemo da nema autokorelacije u rezidualima *(Tabela 14)*:

Tabela 14. Korelogram standardizovanih reziduala posmatrane serije podataka

Q	AC	PAC	Q-Stat	Prob*
(1)	0,046	0,046	1,0263	0,311
(10)	-0,052	-0,054	23,546	0,009
(20)	-0,003	-0,004	33,169	0,032
(30)	0,033	0,017	37,563	0,161

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Nakon toga, testirano je postojanje ARCH efekat u rezidualima:

Tabela 15. Testiranje postojanja ARCH efekta u rezidualima

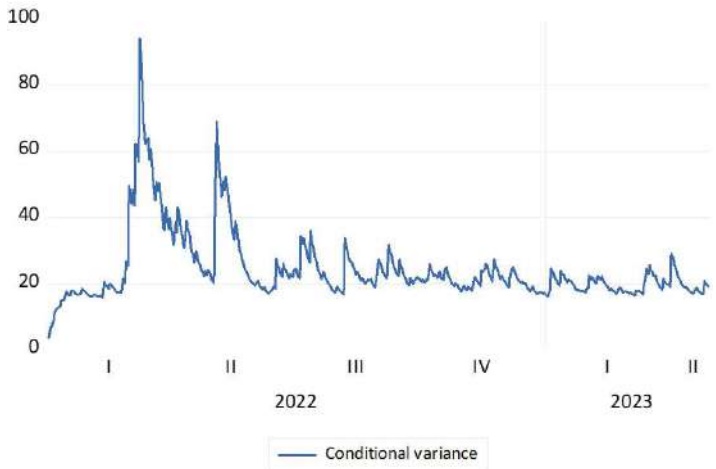
Heteroskedasticity Test: ARCH			
F-statistic	1,016474	Prob. F (1,481)	0,3139
Obs*R-Squared	1,018548	Prob. Chi-Square (1)	0,3129

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Prema vrednostima iskazanim u tabeli 15, ne postoji ARCH efekat u rezidualima posmatrane vremenske serije podataka, jer je p>0,05.

Na grafiku 10 je uslovna varijansa derivirana iz GARCH (1,1) modela:

Grafik 10. Uslovna varijansa derivirana iz GARCH (1,1) modela – OIL/EUR



Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Korelacija volatilnosti rublje i cene nafte na svetskom tržištu

Na osnovu korelacije uslovnih varijansi rublje i nafte deriviranih iz GARCH modela, možemo izvesti odgovarajući zaključak o promenama volatilnosti deviznog kursa rublje pod uticajem volatilnosti sirove nafte tokom krize u Ukrajini. Kako bismo analizirali taj uticaj, prvo smo izračunali nivo korelacije dobijenih vrednosti uslovne varijanse:

Tabela 16. Korelacija uslovnih varijansi rublje i nafte u posmatranom periodu

	RUB/EUR	OIL/EUR
RUB/EUR	1	
OIL/EUR	0,580305	1

Izvor: kalkulacija autora na osnovu podataka https://exchangerates.org.uk/, EViews program

Kao što se može videti iz tabele 16 prisutna je pozitivna korelacija između volatilnosti deviznog kursa rublje i volatilnosti nafte. Na osnovu vrednosti koeficijenta korelacije možemo zaključiti da je u pitanju umerena veza (Evans, 1996; Hinkle et al., 2003) uslovnih varijansi RUB/EUR i OIL/EUR, što je dokaz da je volatilnost rublje pozitivnom korelacijom umerene jačine povezana sa volatilnošću nafte u posmatranom šesnaestomesečnom periodu, tokom kog je otpočela i trajala kriza u Ukrajini, zaključno sa 30. aprilom 2023. godine.

Zaključak

Na osnovu posmatranih vremenskih serija podataka, njihove ekonometrijske analize primenom GARCH modela i izračunavanjem korelacije uslovnih varijansi deriviranih iz odgovarajućih GARCH modela, jasno je da postoji pozitivna i umerena, skoro čvrsta korelacija, između promena volatilnosti nafte i volatilnosti deviznog kursa rublje. Stoga, ovaj istraživački rad je potvrdio ono što smo i pretpostavljali, da vrednost ruske rublje ima pozitivnu i umerenu, ka čvrstoj, povezanost sa vrednošću nafte, čiji je Rusija jedan od vodećih svetskih izvoznika.

Čini se da je upravo u vreme uticaja jednog takvog egzogenog šoka, kakav je ratna kriza u Ukrajini, do srži ogoljena činjenica da ruska ekonomija, odnosno u ovom slučaju valuta rublja kao reprezent ruske ekonomije, jeste u značajnom odnosu međuzavisnosti sa naftom kao prirodnim resursom Rusije, koji se eksploatiše i izvozi u velikim količinama.

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Datum prijema (Date received): 12.11.2023.
Datum prihvatanja (Date accepted): 14.02.2024.

INTERDEPENDENCE OF OIL PRICE VOLATILITY AND RUBLE EXCHANGE RATE DURING THE CRISIS IN UKRAINE

Suzana Balaban [12]Vladimir Pavićević [13]Milica Simić[14]

Abstract

The subject of research in this paper is the impact of the crisis in Ukraine on the volatility of the ruble and oil, as well as the correlation of these values with each other. In order to investigate the impact of the crisis in Ukraine as an external shock on the volatility of the ruble and crude oil, changes in the ratio of their values were analyzed on a daily basis, in the observed period during 2022 and the first four months of 2023. The analysis of time series, and then the comparative analysis of the mentioned data and the use of the GARCH model determined a certain divergence in the very nature of the behavior and movement of the ruble and oil immediately before the beginning and during the crisis in Ukraine, during the observed period. There is no doubt that the Russian currency and crude oil markets behaved much more volatile in this period, which implies a significantly greater impact on economic activities, bearing in mind the instability of the value of the ruble and oil as significant factors affecting the overall economic trends in the world.

Keywords: *ruble, crude oil, comparative analysis, GARCH, correlation*

JEL: *C58 G15 M24*

Introduction

The subject of this research is the value of the RUB/EUR currency pair and crude oil as a commodity that significantly affects the value of currencies and other commodities, i.e. the analysis of the impact of the crisis in Ukraine on the volatility of the ruble and crude oil prices. The research was conducted in the context of the analysis of changes in the value of the Russian ruble and oil in the period from January 1, 2022. until 30.04.2023. The central problem under consideration is the volatility of the value of the ruble and oil under the influence of the current crisis in Ukraine, and their correlation in the specified period. Given that the aforementioned political and economic events significantly influenced the value of the observed variables, the primary goal of this research is to obtain an answer to the question of how much and what are the changes in the value of the

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ruble and oil and the nature of their mutual relationship in the observed period. Accordingly, the research tasks are:

- determination of changes in the value of the RUB/EUR currency pair and the OIL/EUR ratio under the influence of the crisis in Ukraine over a period of sixteen months;
- comparing the value of the ruble and oil in relation to the euro in the specified period;
- calculation and explanation of the value of the correlation matrix, i.e. the correlation coefficient *r* between the conditional variances of the variables: RUB/EUR and OIL/EUR, obtained using the GARCH model.

The initial hypothesis that was tested in the research is as follows: during the crisis in Ukraine, in the observed period, the Russian ruble and oil proved to be moderately correlated values. Through the time series of daily data, the values of ruble and oil were compared against the euro, and similarities and differences were observed. Both observed series of data are presented separately, for a more accurate presentation of the results of the analysis.

The research results are presented descriptively, then through several tables and graphs with comparative results. Using the GARCH model, the volatility of the observed variables was assessed and finally their correlation was calculated.

Literature review

Exchange rates of most economically developed countries of the world fluctuate more or less every day, and long-term trends are especially interesting, important when contracting long-term commercial and financial deals (Obradović et al., 2018). Volatility represents the range and speed of price movement and as such gives the possibility of measuring the risk of certain economic parameters. We have more volatile movements in the value of the RUB/EUR currency pair, for a very logical and well-known reason. First of all, the crisis in Ukraine is directly related to Russia's involvement in both political and economic terms. At the beginning of the Ukrainian crisis, there was an increase in energy prices, and thus the inflation rate in almost all countries of the world, and attention should be paid to agile management methods in order to adapt to changing market conditions (Balaban, Đurašković, 2021).

It is obvious that the rise in the prices of energy and food on world markets since the beginning of the Ukrainian crisis strongly influenced the strengthening of the ruble as the currency of one of the countries with the largest participation in the production and export of energy and food in the world. Russia produces about 18% of non-OPEC production and 12% of total world production in 2021 (Onour, Abdo, 2022).

In order to examine the impact of the crisis in Ukraine on the changes in the value of the ruble and oil as studiously as possible, we will perform an analysis of the volatility of these values in the observed period. This is because one of the basic characteristics of floating exchange rates is high volatility, which manifests itself in several ways (Balaban, 2019), and with it we can qualitatively measure changes in the specified values. In the last few decades, especially after the collapse of the Bretton-Woods agreement on fixed exchange rates, the volatility of exchange rates received special attention in macroeconomic analysis, given that under the influence of the globalization of the world economy, it affects numerous macroeconomic factors.

On the other hand, oil prices and exchange rates are linked to the economy. In fact, both of these data series are closely watched by financial market participants and policymakers. There are various theoretical models in the literature that link oil prices and exchange rates. The seminal papers of Krugman and Golub, both written in 1983, provide theoretical models that form the basis of many empirical results (Anjum, 2019). They argue that oil exporting countries experience an increase in wealth in the short term when oil prices rise, leading to an improvement in the current account balance, i.e. an appreciation of the exchange rate of the oil exporting country's currency.

Analysis of changes in the absolute values of RUB/EUR and OIL/EUR

In order to compare the value of the Russian ruble with oil as a consumer good on the global market, time series data for the Russian ruble and the value of a barrel of oil in relation to the euro were analyzed during the observed period.

Analyzing graph 1, several key points of the daily sections can be observed. It is precisely these key points that distinguish the movement of the value of the Russian ruble against the euro in relation to any other national currency whose value movement would be observed in the analyzed period. The minimum value of the RUB/EUR currency pair in the observed period was on March 7, i.e. March 9, 2022, and was 0.0065 euros for one ruble. As we can see, immediately after the beginning of the crisis in Ukraine, the value of this currency pair weakened from 0.0109 euros for one ruble at the close of February 23, 2022 to 0.0065 euros for one ruble at the close of the market on March 07, 2022. , which is a 40.37% fall of the ruble in the first twelve days since the beginning of the war in Ukraine.

However, the authorities of the Russian Federation make a decision to peg the value of the ruble to the value of an ounce of gold, and at the end of March, a decision to sell energy products: gas and oil exclusively in rubles, defined according to a predetermined payment scheme (Pavićević, 2022). Such economic and political decisions of the Russian authorities have led to an almost constant growth of the ruble against the euro since those events. So already on March 31, 2022, when it was already known that Russia would sell energy products only for

its own currency, the ratio of the RUB/EUR currency pair was close to that at the beginning of the Ukrainian crisis and amounted to 0.011 euros for 1 ruble. The trend continued during the months of April, May and June, so we have the maximum value of the currency pair RUB/EUR on June 29, when the value is 0.0182 euros for one ruble, which is an increase of 180.00% compared to the minimum value of March 7 and March 9, 2022, just fifteen days after the beginning of the crisis in Ukraine.

Graph 1. Movement of the value of the ruble in the period from 01.01.2022. until 30.04.2023.

Source: author's calculation based on data available at https://exchangerates.org.uk/

Like the analysis of the change in the value of the Russian national currency in the given period, for the purposes of this analysis, the euro was taken as the reference value, in order for the comparative analysis to reflect the relationship of the selected variables as qualitatively as possible. Although the price of oil on the stock exchanges is expressed in dollars, here the ratio OIL/EUR is taken as the appropriate parity.

Based on the analysis of Graph 2, increased market volatility can be observed in the oil market, than is usually the case in the volatility of national currencies. If we look at the minimum and maximum value of oil on a daily level at the closing of the market, expressed in euros in the observed period, we will see the percentage changes in the value of oil. One of the minimum values of oil in the observed period was EUR 66.42371, on January 1, 2022, and the maximum value in the same observed period was EUR 116.70415, on March 6, 2022, ten days after the start of the war. crisis in Ukraine. Therefore, the maximum value of oil was higher than its minimum value by 75.70%.

Graph 2. Movement of the value of a barrel of oil in the period from 01.01.2022. until 30.04.2023.

Source: author's calculation based on data available at https://exchangerates.org.uk/

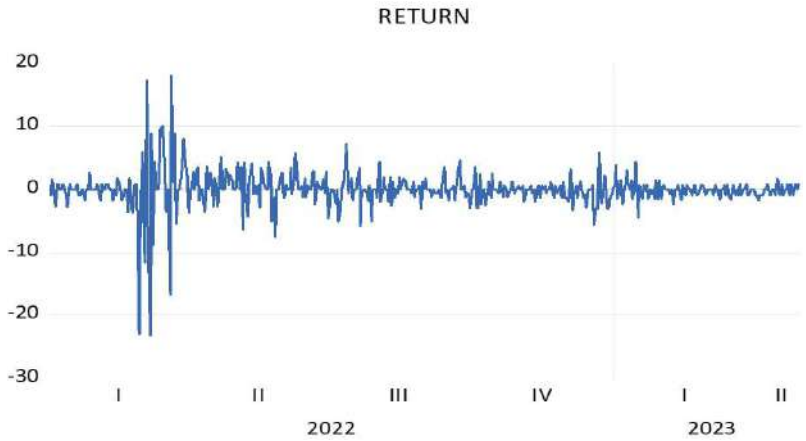
It should be borne in mind that after the peak on the graph, the value of oil, with minor oscillations, mostly decreased, which means that the sudden increase in the price within about two months was predominantly of a speculative nature. This is supported by the fact that on March 18, 2023, while the crisis in Ukraine is still ongoing, the value of oil amounted to EUR 61.71406, which is less than the value at the beginning of 2022. The volatility of oil as a measure of risk, with this ratio, shows a higher risk than investing in oil.

Volatility of the currency pair RUB/EUR during the crisis in Ukraine

The analysis of the volatility of the currency pair RUB/EUR before and during the current crisis in Ukraine included the analysis of 485 data, more precisely the logarithmic daily rates of return of the currency pair RUB/EUR over a period of sixteen months. In the first step, the authors analyzed the volatility grouping of the mentioned time series.

Chart 3 clearly shows that there is a clustering of the volatility of the yield rates of the currency pair RUB/EUR. As the extreme values of the time series of the currency pair RUB/EUR are noticeable in the 1st quarter of 2022, the clustering of the volatility of the time series of logarithmic daily rates of return of the currency pair RUB/EUR shows an identical case, which is the result of the beginning of the war crisis in Ukraine.

Chart 3. Grouping of volatility - currency pair RUB/EUR



Source: author's calculation based on data from EViews program

In the second step, with the help of the Bai-Perron test, the authors evaluate whether a known exogenous event, the beginning of the crisis in Ukraine, had an effect on the appearance of a structural break in the observed time series of data. Based on the test results, we conclude that there is no structural break in the observed time series *(Table 1)*

Table 1. Bai-Perron test result - currency pair RUB/EUR

Bay-Perron test of L+1 vs. L sequentially determined breaks **484 samples included**			
Sequential F-statistic determined breaks: 0			
Break test	F-statistic	Scaled F-statistic	Critical Value
0 vs. 1	1.677169	1.677169	8.58
Significant at the 0.05 level.			

Source: author's calculation based on data from EViews program

Using ADF and KPSS unit root tests, the stationarity of the observed time series was assessed. The ADF test assumes H_0 that the observed series has one unit root, in which case it is not stationary. Given that the probability value is $p<0.05$ in both cases, the observed series does not have a unit root *(Table 2)* i.e. it is stationary, which is of fundamental importance for the continuation of the research.

Table 2. Results of ADF test - currency pair RUB/EUR

Exogenous: Constant		
	t-statistic	Prob.*
Augmented Dickey-Fuller test statistic	-24.96920	0.0000
Exogenous: Constant, Linear Trend		
Augmented Dickey-Fuller test statistic	-24.98543	0.0000

Source: author's calculation based on data from EViews program

In order to verify the obtained results, the KPSS test was applied, which starts from the hypothesis H_0 that the observed time series is stationary. The stationarity of the observed time series is also confirmed by the results of the KPSS test, given that $p>0.05$ in both cases *(Table 3)*

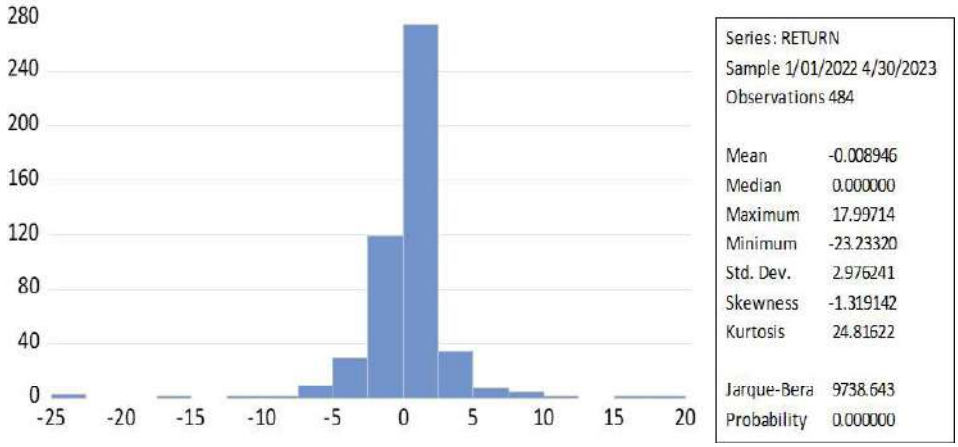
Table 3. Result of KPSS test - currency pair RUB/EUR

Exogenous: Constant	
	LM-Stat.
Kwiatkowski-Philips-Schmidt-Shin test statistic	0.166746
Exogenous: Constant, Linear Trend	
Kwiatkowski-Philips-Schmidt-Shin test statistic	0.068106

Source: author's calculation based on data from EViews program

For a more detailed analysis of the observed time series, descriptive statistics were used (Graph 4). Based on the obtained results of the Jarque-Bera test, it can be concluded that the observed time series does not have a normal distribution, which is visible on the Quantile-Quantile (QQ) histogram (Graph 5). The coefficient of asymmetry is less than 0, which means that the observed time series has a negative asymmetry, while the coefficient of flattening above 3 shows that the observed data series is elongated. The value of the asymmetry coefficient is negative: -3.817822, which shows that it is a pronounced negative asymmetry. The flattening coefficient with the amount of 47.59308 absolutely corresponds to the elongation shown on the histogram (Graph 4) and which is significantly higher than that which is characteristic of a normal distribution.

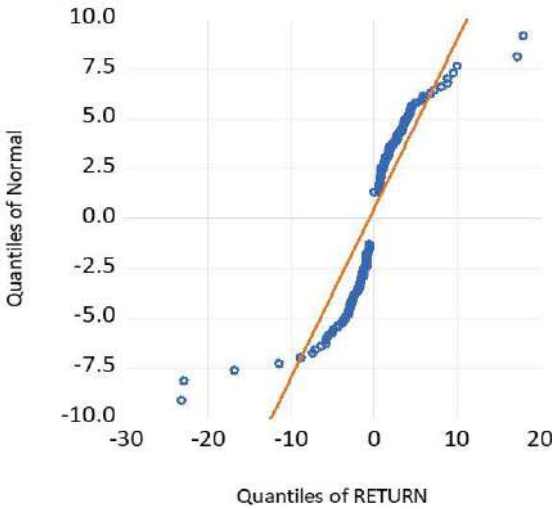
Graph 4. Descriptive statistics - currency pair RUB/EUR



Source: author's calculation based on data from EViews program

As already stated, the finding that the observed data series does not have a normal distribution is confirmed by the following graph:

Graph 5. QQ histogram - currency pair RUB/EUR



Source: author's calculation based on data from EViews program

In further work, the authors investigate autocorrelation in the data of the observed time series. When it comes to autocorrelation and in this analyzed case, we will start from the hypothesis H_0 that there is no autocorrelation in the observed time series of data.

Table 4. Results of the autocorrelation detection test - currency pair RUB/EUR

Q	AC	PAC	Q-Stat	Prob
(1)	0.003	0.003	0.0032	
(10)	-0.052	-0.092	31,828	0.0000
(20)	0.046	-0.007	59,701	0.0000
(30)	-0.027	-0.004	69,038	0.0000

Source: author's calculation based on data from EViews program

Looking at the obtained results on autocorrelation, partial correlation, and Q-statistics and probability, and following the probability on Q (10), Q (20) and Q (30), it can be very simply noticed that in all cases $p<0.05$ which means that the starting hypothesis is not confirmed and that autocorrelation exists. Accordingly, an adequate ARMA specification was determined based on the lowest value Schwarz criterion (SIC) - MA (1) in order to eliminate autocorrelation and perform the heteroskedasticity test.

Heteroskedasticity shows the fact that the variance of a random error is different for different values of a certain independent variable, that is, it does not follow a constant value. In this sense, the authors examine whether there is an ARCH effect, in order to see whether heteroskedasticity occurs, which is very important from the aspect of continuing the research.

Table 5. Results of the ARCH test - currency pair RUB/EUR

Heteroskedasticity Test: ARCH			
F-statistic	19.46771	Prob. F (1,481)	0.0000
Obs*R-Squared	18.78823	Prob. Chi-Square (1)	0.0000

Source: author's calculation based on data from EViews program

Based on the results *(Table 5),* it can be seen that there is an ARCH effect, that is, that $p<0.05$. Using the lowest SICa, the appropriate GARCH model was selected, which in this case is FIGARCH (1,1).

In order to determine whether there is significant autocorrelation in the residuals, the values of Q (1), Q (10), Q (20) and Q (30) are shown on the correlogram of the residuals. In the event that these values in several cases amount to $p>0.05$, then we could conclude that the observed model is good and that there is no significant autocorrelation in the residuals. After determining whether there is autocorrelation in the residuals, it was examined whether the ARCH effect is present in the residuals of the observed data series.

Table 6. Correlogram of standardized residuals - rate of return RUB/EUR

Q	AC	PAC	Q-Stat	Prob*
(1)	-0.008	-0.008	0.0346	0.853
(10)	-0.006	-0.005	5.9895	0.816
(20)	0.029	0.030	6.8213	0.997
(30)	-0.012	-0.010	7.2056	1,000

Source: author's calculation based on data from EViews program

Based on the observed probability values in the sample, we can conclude that the model is good and that there is no significant autocorrelation in the residuals of the observed data series *(Table 6)*

Based on the following table *(Table 7),* it can be concluded based on the obtained probability that there is no ARCH effect in the residuals of the observed time series of data, that is, that the corresponding model is adequately specified.

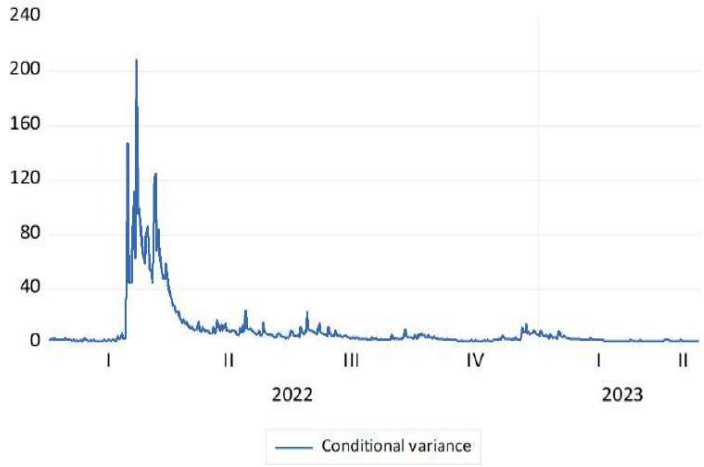
Table 7. Testing the ARCH effect in the residuals – currency pair RUB/EUR

Heteroskedasticity Test: ARCH			
F-statistic	0.034141	Prob. F (1,481)	0.8535
Obs*R-Squared	0.034281	Prob. Chi-Square (1)	0.8531

Source: author's calculation based on data from EViews program

Graph 6 shows the conditional variance derived from the FIGARCH (1,1) model, which shows the volatility of the time series of logarithmic daily rates of return of the currency pair RUB/EUR, which is a condition for calculating the correlation between the volatility of the Russian ruble and the volatility of oil prices, which is the subject research work.

Graph 6. Conditional variance derived from the FIGARCH (1,1) model - pair RUB/EUR



Source: author's calculation based on data from EViews program

Oil price volatility during the crisis in Ukraine

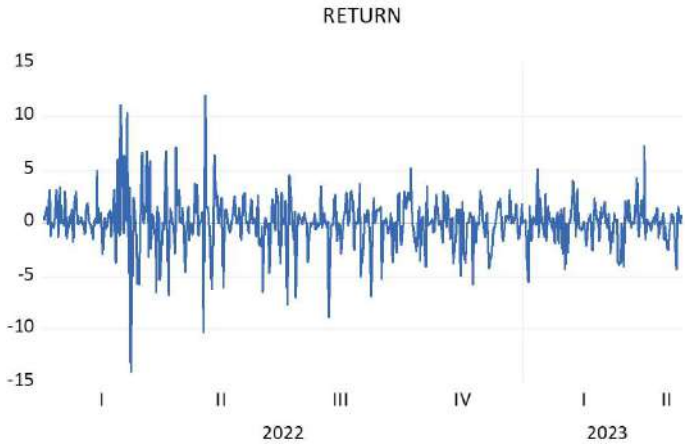
Analysis of the change in the value of crude oil expressed in euros OIL/EUR, before and during the current crisis in Ukraine, implies a logarithmic daily rate of return. Accordingly, a sample of 485 data was analyzed. As one of the characteristics, the grouping of volatility of the time series of logarithmic daily rates of oil value expressed in euros was analyzed, which is not usual, so that this relationship could be adequately compared with the currency pair RUB/EUR.

As can be seen in graphic 7, with small changes in the value of the yield rates, small changes in the value of the observed OIL/EUR series are observed, while with larger changes in the value of the yield rates of the given time series, we have large changes in the observed series of OIL/EUR values. Also, the extreme values of the OIL/EUR time series are observed in the 1st and 2nd quarter of 2022, which was also shown by the grouping of the volatility of the time series of the logarithmic daily yield rates of the crude oil value, which is a consequence of the war crisis in Ukraine.

With the help of the structural break test, using the Bai-Perron procedure, it was examined whether the observed exogenous event, i.e. the beginning of the war crisis in Ukraine, had an effect on the occurrence of structural break in the observed time series of data. Based on the test results *(Table 8),* it was concluded that there are no defined structural breaks in the observed time series of data, caused by an exogenous event, that is, in this case, the beginning of the crisis in Ukraine.

Here is a graphical representation of the volatility grouping for OIL/EUR:

Graph 7. Grouping of volatility - OIL/EUR



Source: author's calculation based on data from EViews program

As previously stated, a structural fracture test follows, using the Bai-Perron procedure:

Table 8. Bai-Perron test result - OIL/EUR

Bay-Perron test of L+1 vs. L sequentially determined breaks **484 data included**			
Sequential F-statistic determined breaks: 0			
Break test	F-statistic	Scaled F-statistic	Critical Value
0 vs. 1	1.677169	1.677169	8.58
Significant at the 0.05 level.			

Source: author's calculation based on data from EViews program

As in the previous case, by applying ADF and KPSS unit root tests, the authors check whether the observed time series of data is stationary.

Based on the obtained results of the ADF test *(Table 9),* we can conclude that the observed series of logarithmic daily return rates of the OIL/EUR value is stationary.

Table 9. Results of the ADF test - OIL/EUR

Exogenous: Constant		
	t-statistic	Prob.*
Augmented Dickey-Fuller test statistic	-22.29421	0.0000
Exogenous: Constant, Linear Trend		
Augmented Dickey-Fuller test statistic	-22.35367	0.0000

Source: author's calculation based on data from EViews program

Based on the obtained results of the KPSS test, it can be concluded, as with the previous application of the ADF test, that the observed time series of data is stationary *(Table 10)*

Table 10. Results of KPSS test - OIL/EUR

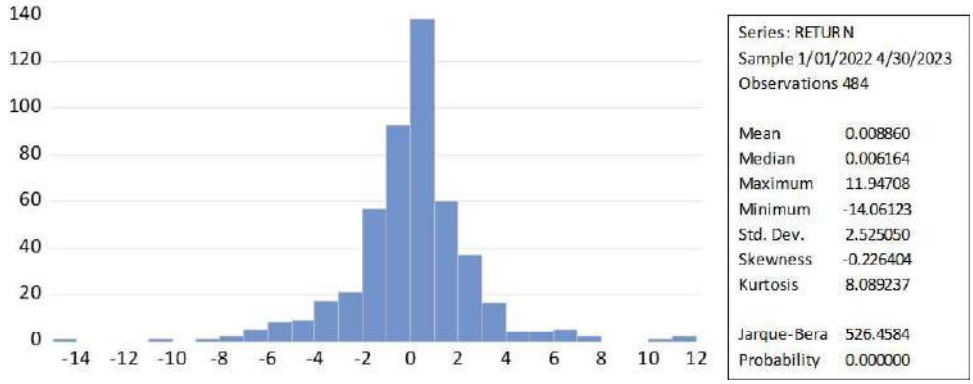
Exogenous: Constant	
	LM-Stat.
Kwiatkowski-Philips-Schmidt-Shin test statistic	0.242345
Exogenous: Constant, Linear Trend	
Kwiatkowski-Philips-Schmidt-Shin test statistic	0.065226

Source: author's calculation based on data from EViews program

In order to better describe the data of the observed time series, descriptive statistics are presented. The Jarque-Bera statistic tests the normality of the distribution.

Based on the obtained results (Graph 8), it can be seen that the value is $p<0.05$, which implies that the observed OIL/EUR data series does not have a normal distribution and significantly deviates from the mean value, which is also confirmed by the QQ histogram (Graph 9). The coefficient of asymmetry is -0.226404, and the observed time series of data is characterized by negative asymmetry, while according to the same table, the coefficient of flattening is 8.089237. Its large amount means that the observed data series is elongated, because the flattening coefficient is significantly higher than 3.

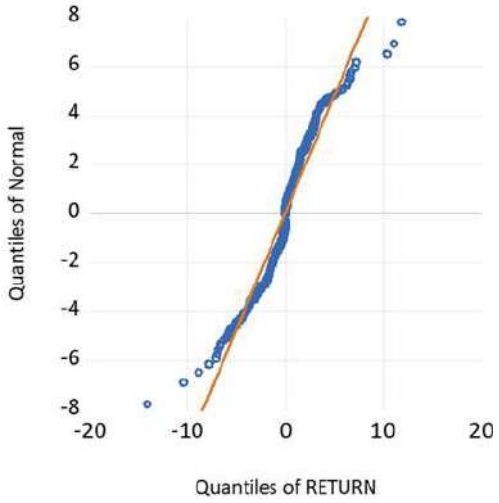
Graph 8. Descriptive statistics - OIL/EUR



Source: author's calculation based on data from EViews program

Next is the QQ histogram, which confirms that there is no normal distribution.

Graph 9. QQ histogram – OIL/EUR



Source: author's calculation based on data from EViews program

When it comes to autocorrelation, in this case too, the hypothesis H_{0} is used there is no correlation in the observed time series of residuals. Based on the obtained data on autocorrelation, partial correlation, Q statistics and probability, and following the probability on the Q(1), Q(10), Q(20) and Q(30) sample, it can be very simply observed that in all observed cases $p>0.05$, which means that the starting hypothesis is confirmed and that there is no autocorrelation in the observed time series of data *(Table 11)* Using the LM serial correlation test, the same result was obtained *(Table 12)* It can be argued that there is no autocorrelation in the observed time series of data given that the probability is $p>0.05$.

Table 11. Results of the autocorrelation detection test - OIL/EUR

Q	AC	PAC	Q-Stat	Prob
(1)	-0.0016	-0.0016	0.1321	0.716
(10)	-0.021	-0.014	9.7774	0.460
(20)	0.034	-0.033	25,576	0.180
(30)	-0.002	-0.033	40,034	0.104

Source: author's calculation based on data from EViews program

Table 12. Results of the LM test for detecting autocorrelation - OIL/EUR

Breusch-Godfrey Serial Correlation LM Test **H0: No serial correlation at up to 2 lags**			
F-Statistic	0.225217	Prob. F (2,481)	0.7984
Obs*R-Squared	0.452819	Prob. Chi-Square (2)	0.7974

Source: author's calculation based on data from EViews program

The next step performed is heteroskedasticity testing. Based on the obtained results *(Table 13),* we can see that there is an ARCH effect, since $p<0.05$.

Table 13. Results of the ARCH test – OIL/EUR

Heteroskedasticity Test: ARCH			
F-statistic	5.499866	Prob. F (1,481)	0.0194
Obs*R-Squared	5.460300	Prob. Chi-Square (1)	0.0195

Source: author's calculation based on data from EViews program

Based on the calculated value of the lowest SIC criterion, the GARCH (1,1) model was chosen. In order to determine the adequacy of the selected model, the existence of autocorrelation and heteroskedasticity in the residuals of the evaluated model was tested. Based on the observed values, we conclude that there is no autocorrelation in the residuals *(Table 14)*

Table 14. Correlogram of standardized residuals of the observed data series

Q	AC	PAC	Q-Stat	Prob*
(1)	0.046	0.046	1.0263	0.311
(10)	-0.052	-0.054	23,546	0.009
(20)	-0.003	-0.004	33,169	0.032
(30)	0.033	0.017	37,563	0.161

Source: author's calculation based on data from EViews program

After that, the existence of the ARCH effect in the residuals was tested:

Table 15. Testing the existence of the ARCH effect in the residuals

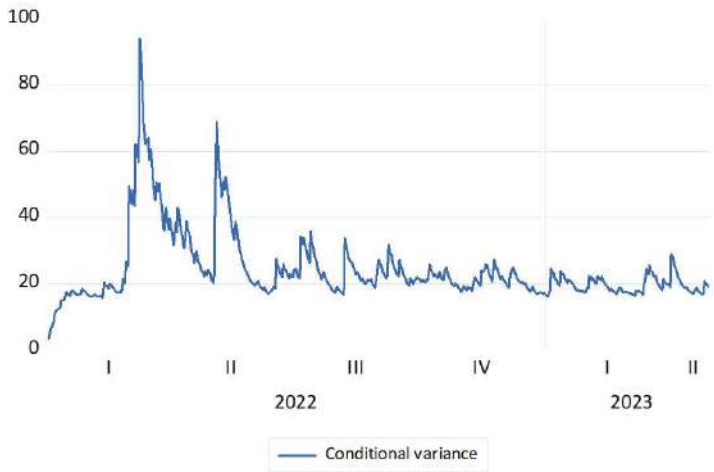
Heteroskedasticity Test: ARCH			
F-statistic	1.016474	Prob. F (1,481)	0.3139
Obs*R-Squared	1.018548	Prob. Chi-Square (1)	0.3129

Source: author's calculation based on data from EViews program

According to the values shown in table 15, there is no ARCH effect in the residuals of the observed time series of data, because p>0.05.

Graph 10 shows the conditional variance derived from the GARCH (1,1) model:

Graph 10. Conditional variance derived from the GARCH (1,1) model – OIL/EUR



Source: author's calculation based on data from EViews program

Correlation of ruble volatility and oil prices on the world market

Based on the correlation of the conditional variances of the ruble and oil derived from the GARCH model, we can draw an appropriate conclusion about the changes in the volatility of the exchange rate of the ruble under the influence of the volatility of crude oil during the crisis in Ukraine. In order to analyze that influence, we first calculated the correlation level of the obtained conditional variance values:

Table 16. Correlation of the conditional variances of the ruble and oil in the observed period

	RUB/EUR	OIL/EUR
RUB/EUR	1	
OIL/EUR	0.580305	1

Source: author's calculation based on data from EViews program

As can be seen from table 16, there is a positive correlation between the volatility of the exchange rate of the ruble and the volatility of oil. Based on the value of the correlation coefficient, we can conclude that there is a moderate connection (Evans, 1996; Hinkle et al., 2003) of the conditional variances of RUB/EUR and OIL/EUR, which is proof that the volatility of the ruble is related to the volatility of oil by a positive correlation of moderate strength. in the observed sixteen-month period, during which the crisis in Ukraine began and lasted, ending on April 30, 2023.

Conclusion

Based on the observed time series of data, their econometric analysis using the GARCH model and the calculation of the correlation of conditional variances derived from the corresponding GARCH models, it is clear that there is a positive and moderate, almost strong correlation between the changes in oil volatility and the volatility of the ruble exchange rate. Therefore, this research paper confirmed what we assumed, that the value of the Russian ruble has a positive and moderate, to strong, connection with the value of oil, of which Russia is one of the world's leading exporters.

It seems that precisely at the time of the influence of such an exogenous shock, such as the war crisis in Ukraine, the fact that the Russian economy, or in this case the ruble currency as a representative of the Russian economy, is in a significant relationship of interdependence with oil as a natural resource of Russia is exposed to the core. which is exploited and exported in large quantities.

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