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Effectiveness of Foreign Exchange Interventions: Evidence and Lessons from Chile*

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Abstract

In this article we evaluate the effectiveness of the last four foreign exchange interventions (FXI) of the Central Bank of Chile (CBC). Using daily and intraday data of the nominal exchange rate, the results show through different empirical methods (local projections, event study, SDID) that both interventions aimed at solving volatility problems in the FX market (dated in 2019 and 2022) were effective, meaning they significantly reduced exchange rate volatility. The results support the implications of the different mechanisms that have been proposed in the literature to understand the effects of FXI. At the same time, these results suggest that intervening in the forward market appears to be as effective as intervening in the spot market.

Resumen

En este artículo evaluamos la efectividad de las últimas cuatro intervenciones cambiarias (FXI) del Banco Central de Chile (BCCh). Utilizando datos diarios e intradiarios del tipo de cambio nominal, los resultados muestran a través de diferentes métodos empíricos (proyecciones locales, estudio de eventos, SDID) que ambas intervenciones orientadas a resolver problemas de volatilidad en el mercado cambiario (en 2019 y 2022) fueron efectivas, es decir, redujeron significativamente la volatilidad del tipo de cambio. Los resultados apoyan las implicancias de diferentes mecanismos que se han propuesto en la literatura para entender los efectos de las FXI. Al mismo tiempo, estos resultados sugieren que intervenir en el mercado forward parece ser tan efectivo como intervenir en el mercado spot.

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1. Introduction

Foreign exchange interventions (FXI) are part of the set of tools that Central Banks possess to achieve their objectives. Naturally, in contexts with a fixed exchange rate or within a band, the monetary authority must dedicate a large part of its work to maintaining the promised level by constantly intervening in the foreign exchange (FX) market.

Likewise, in regimes with floating exchange rates, such interventions have been popular in developing economies. They are motivated by a wide range of objectives such as accumulation of reserves, management of inflationary pass-through, mitigation of financial stability risks and control of exchange rate volatility (Chamon et al. 2019; Itskhoki and Mukhin 2023).

Recently, the Central Bank of Chile (CBC) intervened in the FX market on four occasions, in 2019, 2021, 2022 and 2023.[1] Although Chile has had a floating exchange rate system since 1999, the CBC reserves the right to intervene in parity exchange. This is done through currency purchase or sale operations and is carried out on exceptional occasions that compromise the proper functioning of the financial market, or in order to increase international reserves.

In particular, two of these intervention episodes (2019 and 2022) were preceded by strong and rapid depreciative pressure on the exchange rate, which generated excessive volatility. While in the others (2021 and 2023) the objective was to increase international reserves.

In this article we empirically evaluate the effectiveness of these intervention episodes using different econometric approaches. For interventions that are motivated by problems in the FX market (such as in November 2019 or July 2022), the effectiveness of an FXI is understood as the correction to such problems, for example, by reducing volatility in the FX market. While for FXI that seek to increase international reserves, their effectiveness lies in fulfilling a high percentage of the announced amount in purchases without causing distortions in the FX market.

One way to theoretically justify the effectiveness of sterilized FXI is through certain frictions that induce the famous *impossible trinity* to non-compliance.[2] On the one hand, in the portfolio channel, the imperfect substitution between assets in national and foreign currency makes it possible for these interventions to have an effect on the exchange rate by moving the relative supply of foreign currency (Kouri 1976; Branson and Henderson 1985; Gabaix and Maggiori 2015; Fanelli and Straub 2021). Other frictions are of the informational

[1] These interventions were sterilized, that is, the counterpart of operations in national currency was neutralized in order to keep the monetary policy rate (or monetary base, in other policy schemes) constant. In what follows, we only speak of exchange rate interventions, referring to sterilized interventions, unless otherwise mentioned.

[2] The *impossible trinity* refers to the theoretical impossibility of having an independent monetary policy along with exchange rate objectives, in a context of perfect capital mobility.

type, so if a misalignment between the exchange rate and its fundamentals occurs as a result of said frictions, the monetary authority could use FXI to correct information asymmetries (Frankel and Froot 1990). On the other hand, non-instantaneous movements in capital flows (Ghosh, Ostry, and Chamon 2016), or segmented financial markets with frictional violations of uncovered interest rate parity (UIP) (Itskhoki and Mukhin 2023) also make it possible to justify the effectiveness of these interventions.

However, the signalling channel suggests that FXI have an effect on the exchange rate by providing information on future monetary policy, without violating the *impossible trinity* (Mussa 1981).

Note that these mechanisms are not mutually exclusive, and it is very likely that in practice they will be present simultaneously during an intervention episode.

Regarding the empirical evidence on the effects and effectiveness of FXI, there is a vast literature that tries to verify and quantify this effect, facing the related endogeneity problems (Sarno and Taylor 2001; Menkhoff 2010; Blanchard, Adler, and de Carvalho Filho 2015; Fratzscher et al. 2019; Chamon, Garcia, and Souza 2017; Chamon et al. 2019). In general, it seems that these interventions have a significant effect in the expected direction,[3] both on the level and on the volatility of the exchange rate. However, the magnitude of the effects is rather small. In a recent meta-analysis of 74 empirical articles covering a period of five decades (1970 - 2020) for 19 countries, it is found that, on average, the exchange rate moves 1% in the face of an intervention of $ 1 billion USD, while its volatility decreased by 0.6% for the same amount of intervention (Arango-Lozano et al. 2020).

Although the event study methodology is one of the most common in empirical exercises of this type (Contreras et al. 2013; Echavarría, Fernando Melo, and Villamizar 2014; Durán-Vanegas et al. 2016; Larraín and Saravia 2019), other strategies have also been used that exploit the availability of data and some rules of intervention specific to each country. For example, panel data strategies (Adler, Lisack, and Mano 2019), regression discontinuity designs (Vargas, Cardozo, and Villamizar 2019), instrumental variables (Adler and Tovar 2014; Domanski, Kohlscheen, and Moreno 2016; Menkhoff, Rieth, and Stöhr 2021)), synthetic controls (Chamon, Garcia, and Souza 2017) and autoregressive vector models (Blanchard, Adler, and de Carvalho Filho 2015; Menkhoff, Rieth, and Stöhr 2021)).

As for the heterogeneity of the effect of FXI, it has been documented that a greater degree of financial openness (Adler and Tovar 2014; Arango-Lozano et al. 2020), or independence of the monetary authority (Arango-Lozano et al. 2020), seems to decrease the effect. The latter is consistent from a theoretical perspective with the presence of

[3] While uncovered interest rate parity (UIP) implies that sterilized FXI has no effect on the exchange rate, certain frictions allow effects to occur (see Section 2). According to the portfolio channel, a sale of foreign currency expands the relative supply of that currency, and thus the expected effect is an appreciation of the local currency. Thus, when we talk about the "expected direction" of an intervention, we mean that, if there is an effect, it occurs in accordance with the prediction of the portfolio channel.

frictions that weaken the *impossible trinity*.

On the other hand, the larger the amounts to be traded in each intervention, the greater its effect (Adler and Tovar 2014; Fratzscher et al. 2019; Arango-Lozano et al. 2020). This supports one of the implications of the portfolio channel. According to this mechanism, the more the relative supply of foreign exchange is displaced, the greater the effect.

With respect to the way that FXI are communicated, the evidence for Latin American countries suggests that the more transparent the information provided to the public about the intervention, the smaller the effect (Adler and Tovar 2014). However, for episodes in which the start of an FXI is announced, the magnitude of the effect of the announcement is greater than that of the intervention itself (Tapia and Tokman 2004; Echavarría, Melo-Velandia, and Villamizar-Villegas 2018). The latter can be considered as evidence in favour of the signalling channel, due to agents taking these announcements as hints of the direction of future monetary policy.

Empirical evidence for Latin America has focused on those countries with a higher frequency of FXI episodes, such as Brazil, Colombia, and Peru. For the case of Brazil interventions largely use forward instruments for operations (Walker 2019). Chamon, Garcia, and Souza (2017) use a synthetic control methodology to estimate the effects of a pre-announced FXI programme in Brazil in 2013. They find effects in the expected direction and significant on the level and volatility of the exchange rate, although of short duration. Instead, Viola et al. (2019) document effects on volatility in both directions in different intervention episodes in Brazil.

In Peru FXI are more frequent. They are characterized by being rather discretionary and using, to a greater extent, the *spot* market for operations. Evidence suggests that FXI in Peru have been effective in reducing exchange rate volatility (Durán-Vanegas et al. 2016; Castillo et al. 2019).

A 2019 study by the Bank for International Settlements uses a regression discontinuity design to estimate the effect of interventions between 2002 and 2012 in Colombia. The study finds that the exchange rate moves on average 2% in the first week of intervention. It also emphasizes the degree of market uncertainty, which can amplify the former effect by up to 2 percentage points (Vargas, Cardozo, and Villamizar 2019).

One of the characteristics of FXI in Colombia is that they have had episodes in which FXI have been discretionary (2004 - 2007), and others in which they have been well publicized and pre-announced (2008 - 2014). The evidence shows that the magnitude of the effect of interest is greater when the interventions are pre-announced, and at the same time this effect is amplified when the monetary authority has greater credibility (Echavarría, Melo-Velandia, and Villamizar-Villegas 2018; Pinzón-Puerto and Villamizar-Villegas 2023).

FXI in Chile have been exceptional, or at least until 2019. Since the floating exchange

rate regime began in 1999, the CBC has intervened on eight occasions: four to buy foreign currency and increase its international reserves (March 2008, January 2011, January 2021, and June 2023), and four others to sell foreign currency with the aim of correcting exchange rate volatility problems (August 2001, October 2002, December 2019 and July 2022).

On the evidence of the effectiveness of these interventions, significant effects have been found in the direction of reducing exchange rate volatility (Tapia and Tokman 2004; Larraín and Saravia 2019; Jara and Piña 2023). A highlight of the literature is that the effect of the intervention announcements have greater effects than the interventions themselves (Tapia and Tokman 2004; Fuentes et al. 2014; Larraín and Saravia 2019).

However, there is also evidence of insignificant effects of some of these interventions, either on the level or volatility of the exchange rate (Broto 2013). Moreover, as only four FXI had been produced before 2019, the stabilizing role of these was not so clear (Gamboa-Estrada 2019).

This article provides evidence in favour of the effectiveness of recent FXI, both in solving problems of volatility in the FX market and in accumulating international reserves without putting pressure on the exchange rate.

We use different econometric approaches to evaluate the effect of FXI on the exchange rate. First, using daily data and controlling for exchange rate fundamentals, we estimate the dynamic effect of FXI on the daily return and volatility of the exchange rate using local projections (Jordà 2005). Furthermore, we decompose the total effect between the effect of the announcement, the intervention itself, and the amounts sold in spot dollars and *non-deliverable forward* (NDF) contracts.

Then, using intraday data and an event study methodology, we estimate the effect on the exchange rate of two announcements during the 2022 FXI. These announcements were published by the CBC when the market was open, so we assess their effect on the prices of the transactions that occurred moments after these announcements.

Finally, we use the recent Synthetic Difference-in-Differences (SDID) method (Arkhangelsky et al. 2021) to construct a counterfactual with a sample of emerging market currencies, both of the daily return and volatility of the exchange rate. The effects of the four intervention episodes is estimated using these counterfactuals.

The results show that the 2019 and 2022 interventions, aimed at correcting exchange rate volatility problems, were effective. While the immediate effect on volatility is an increase of 0.2 and 0.3 pp, respectively, after 30 days from the start of each intervention the cumulative effects are a decrease of 1.2 and 0.6 pp, respectively. The estimates using the SDID method show results in the same direction, although of lower magnitudes. However, when the estimation window considers only a few days after the start of each intervention, the results are similar in magnitude.

On the other hand, as regards the effects on the daily return of the exchange

rate, the total effect was a decrease of 2.5 and 6.2 percentage points (pp), respectively. Announcements were the main contributors to this effect (-2 and -6 pp, respectively).

These results support the presence of both channels through which FXI have the potential to affect the exchange rate, the portfolio channel and the signalling channel. On the one hand, the portfolio channel predicts that the magnitude of the effect of the intervention is greater the larger the amounts to be traded. Thus, a larger effect associated with the 2022 intervention is interpreted as evidence in favour of this mechanism because the traded amount was almost double that of the 2019 episode. On the other hand, intervention announcements were also found to have a greater effect than the intervention itself, which is consistent with the signalling channel premise. Moreover, intraday data show that the first announcement on the amounts to be traded in the first week of the 2022 FXI had an additional effect on the exchange rate appreciation trend on that day (on which FXI operations had not yet started).

It is important to note that in these interventions the CBC did not have to sell the maximum announced. It only sold 26% and 62% of the maximum amounts announced in spot dollars, for the FXI of 2019 and 2022 respectively.

Regarding dollar purchase programs, the results show that the 2021 program had no significant effects on the daily return of the exchange rate, and a cumulative effect of -0.4 pp on volatility. In addition, 62% of the total announced purchases were completed.

In contrast, the 2023 dollar purchase program had a depreciating effect on the exchange rate, increasing its daily return by 2.5 pp. Moreover, at that time the Chilean exchange rate was under other depreciating pressures, as the CBC was unwinding its selling position in NDF contracts from the 2022 FXI, and non-resident investors were also betting against the Chilean peso in the forward market.[4] It was in this context that the CBC suspended the dollar purchase program when only 37% of the total announced had been purchased.

These results contribute to the literature on the effectiveness of FXI in three ways. First, they provide evidence of recent FXI in a small, open economy like Chile. Such an economy is exposed to FX market problems and FXI can be an effective tool to combat them. Second, they provide partial evidence on the effectiveness of intervening between the spot or forward market. In both the 2019 and 2022 FXI the CBC intervened in both markets and the results show that it is not possible to reject the null hypothesis of equal effects. This is important since intervening by selling spot dollars incurs a direct cost for international reserves, while using NDF contracts as an instrument does not have such a cost. Finally, we employ a recent method (SDID) to improve the identification of the effect of interest.

In what follows, Section 2 presents how FXI are framed in inflation targeting schemes.

[4]The latter is due to the fact that in July 2023 the CBC started the cycle of monetary policy rate cuts, causing movements in rate differentials with respect to the US and other Latin American countries, thus generating carry trade opportunities.

Section 3 explains the case of Chile and its FXI. Section 4 presents and discusses the results of different empirical exercises to assess the effectiveness of the last four FXI of the CBC. Finally, Sections 5 and 6 discusses and concludes the lessons learned from the results.

2. FXI in Inflation Targeting Regimes

An independent monetary policy tends to require a flexible exchange rate in order to adjust and absorb the effects of various shocks. This allows a local monetary policy to respond differently than other countries with larger financial markets' monetary policies to achieve its objectives, primarily with regard to inflation (CBC 2020a).

However, excessive volatility in exchange rates can be detrimental to the economy by distorting the formation of market prices and disrupting the proper allocation of resources. Such volatility can lead to inflationary effects, heightened uncertainty, and reduced confidence among economic agents (García 2022). To prevent these adverse outcomes, it is vital to have a well-regulated financial system and a credible monetary policy that can manage volatility effectively. In addition, tools like FXI can be implemented to address issues of excessive volatility.

The theory of uncovered interest rate parity (UIP) highlights that sterilized FXI do not have a direct impact on the exchange rate, which depends exclusively on the interest rate differential and depreciation expectations.[5] That is,

$$e_t = \mathcal{E}_t(e_{t+1}) + i_t^* - i_t,$$

where e_t is the logarithm of the nominal exchange rate, i_t is the domestic interest rate and i_t^* is the foreign interest rate.

To gauge the potential effectiveness of FXI, one way is to justify the non-fulfilment of UIP resulting from the presence of specific frictions.

One of the arguments supporting the potential effects of FXI is the portfolio channel. The existence of imperfect substitution between domestic and foreign assets permits portfolio adjustment by investors, as changes in the relative supply of these assets through FXI by the monetary authority can affect risk premia (Chamon and Magud 2019). This channel states that changes in the risk premium can explain the effects of FXI, and has been discussed in earlier literature (Kouri 1976; Branson and Henderson 1985; Tapia and Tokman 2004).

One of the key implications of this mechanism is that the effects of FXI relies on the size of the trading volumes relative to the market. In other words, the relative supply of these assets must move sufficiently in order to produce an impact. Empirical evidence

[5] Furthermore, given that we are discussing sterilized interventions, there are no movements in the monetary policy rate.

supports this notion, as the effects of FXI tends to increase with larger trading volumes during the intervention (Adler and Tovar 2014; Fratzscher et al. 2019; Arango-Lozano et al. 2020).

Other types of frictions have also been studied to justify the effects of sterilized interventions, such as segmented financial markets with frictional violations of UIP (Itskhoki and Mukhin 2023), capital flows with non-instantaneous movements (Ghosh, Ostry, and Chamon 2016) or frictions in price formation (Frankel and Froot 1990).

Furthermore, mechanisms have been proposed to explain the effects of these interventions without resorting to a violation of the UIP. One of the most extensively studied mechanisms is the signalling channel (Mussa 1981; Blanchard, Adler, and de Carvalho Filho 2015). This mechanism is based on the premise that Central Banks have superior information compared to other market agents regarding fundamental variables. Therefore, interventions can be seen as signals of future monetary policy. As a result, market agents adjust their portfolios of national and foreign currency, which can lead to changes in the exchange rate (Tapia and Tokman 2004). The signalling channel is consistent with the UIP since it suggests that movements in future rates could impact the exchange rate through the expectations of future exchange rates (Chamon and Magud 2019).

It should be noted that the signalling channel requires Central Banks to have better information about fundamental variables than the rest of the market or a longer-term fundamental-based view. Additionally, the credibility component of Central Banks is necessary for these signals to have an effect. At the same time, an open communication strategy for announcements and details of FXI are required.

It is worth noting that the mechanisms mentioned above are not mutually exclusive, and some studies have partially documented the presence of both. However, it appears that the signalling channel has a more significant impact on the exchange rate (Tapia and Tokman 2004; Fuentes et al. 2014; Echavarría, Melo-Velandia, and Villamizar-Villegas 2018).

3. The case of Chile

Since 1999, Chile has had a free-floating exchange rate system, which is considered necessary for managing an independent monetary policy under an inflation targeting regime.

The exchange rate policy of the Central Bank of Chile (CBC) reflects the option to intervene in the market when there is an overreaction in the exchange rate, meaning when the exchange rate experiences sharp increases or decreases without significant changes in its fundamental determinants over a short period of time (CBC 2020a).

Making the decision to intervene in the FX market is not an easy task. First, it is

essential to have a deep understanding of the determinants of the exchange rate in order to identify abnormal movements in this price that are not explained by movements in these fundamental variables. García (2022) mentions global and local factors that determine the volatility of the nominal exchange rate. The correlation between the exchange rate and the multilateral dollar, the interest rate differential between Chile and the US, variables related to the internal savings-investment balance (current account), and local uncertainty indicators are highlighted.

However, the above is not enough, as it is difficult to accurately determine an overreaction in the FX market, so any decision to intervene is extensively analysed by the CBC.

Since the implementation of the floating exchange rate system, the CBC has intervened on eight occasions: in August 2001, October 2002, March 2008, January 2011, December 2019, January 2021, July 2022, and June 2023. However, only the interventions in 2001, 2002, 2019, and 2022 were motivated by the need to correct problems of volatility in the FX market, and in those cases the direction of the intervention was the sale of currencies. In the episodes of 2008, 2011, 2021 and 2023, the objective was the accumulation of international reserves, so the CBC bought currencies.

In Tapia and Tokman (2004), an analysis of the effects of FXI on the exchange rate between 1998 and 2003 is carried out. Using time-series estimates, they find that the announcements of interventions have a greater impact on the level of the exchange rate, while the interventions themselves have insignificant effects (Tapia and Tokman 2004). This supports the signalling channel as the relevant mechanism behind the effects.

Regarding the interventions in 2008 and 2011 (in which the CBC bought foreign currencies), Fuentes et al. (2014) concluded that the announcements of these interventions had significant and persistent effects on the exchange rate level. In contrast, Broto (2013) documented an increase in exchange rate volatility associated with these two intervention episodes, but insignificant effects on level of the exchange rate.

Larraín and Saravia (2019) use event study models to evaluate the effects of interventions in 2001, 2002, 2008, and 2011. Similar to Tapia and Tokman (2004) and Fuentes et al. (2014), they find greater effects on the level of the exchange rate and its trend from intervention announcements than from the intervention itself.

Recently, Jara and Piña (2023) employed autoregressive heteroscedasticity models for the exchange rate volatility. Using the local projections method (Jordà 2005), they find that the 2019 intervention had a significant negative effect on the currency volatility.

3.1. Details of Recent FXI

In the last five years the CBC has intervened the FX market in four episodes. As mentioned previously, two of these episodes (2019 and 2022) were motivated by volatility problems in

TABLE 1. FXI details

FXI		2019	2021	2022	2023
Announcement		28/11/2019	13/01/2021	14/07/2022	09/06/2023
Start		02/12/2019	18/01/2021	18/07/2022	13/06/2023
End		03/01/2020	13/10/2021	30/09/2022	26/10/2023
Duration (days)		25	193	55	98
Spot amounts	Max announced	10,000 (3.6%)	12,000 (3.8%)	10,000 (3.3%)	10,000 (3.0%)
million USD (% GDP)	Total traded	2,550 (0.9%)	7,440 (2.4%)	6,150 (2.0%)	3,680 (1.1%)
	Daily average	116 (0.04%)	40 (0.01%)	118 (0.04%)	40 (0.01%)
NDF amounts	Max announced	10,000 (3.6%)	-	10,000 (3.3%)	-
million USD (% GDP)	Total traded	4,875 (1.8%)	-	9,950 (3.3%)	-
	Daily average$^{(*)}$	122 (0.04%)	-	254 (0.08%)	-

Note: the end of each intervention is considered to be the moment in which spot operations end. (*) For NDF amounts, the daily average is calculated only for positive variations in the daily NDF stock.

the FX market, while the other two episodes (2021 and 2023) sought to increase the CBC's international reserves.

These FXI share the same operational structure and communication strategy. For the 2021 and 2023 interventions, the CBC purchased spot dollars through public tenders in the *formal exchange market* (*Mercado Cambiario Formal* in Spanish). While for the 2019 and 2022 interventions, in addition to selling spot dollars, the CBC sold non-deliverable forward (NDF) instruments. Spot transactions in dollars involve the exchange of currency at the current market exchange rate, while NDF transactions are carried out through contracts that adjust the spot price by the differential of CLP/USD interest rates (de Ramón 2020).

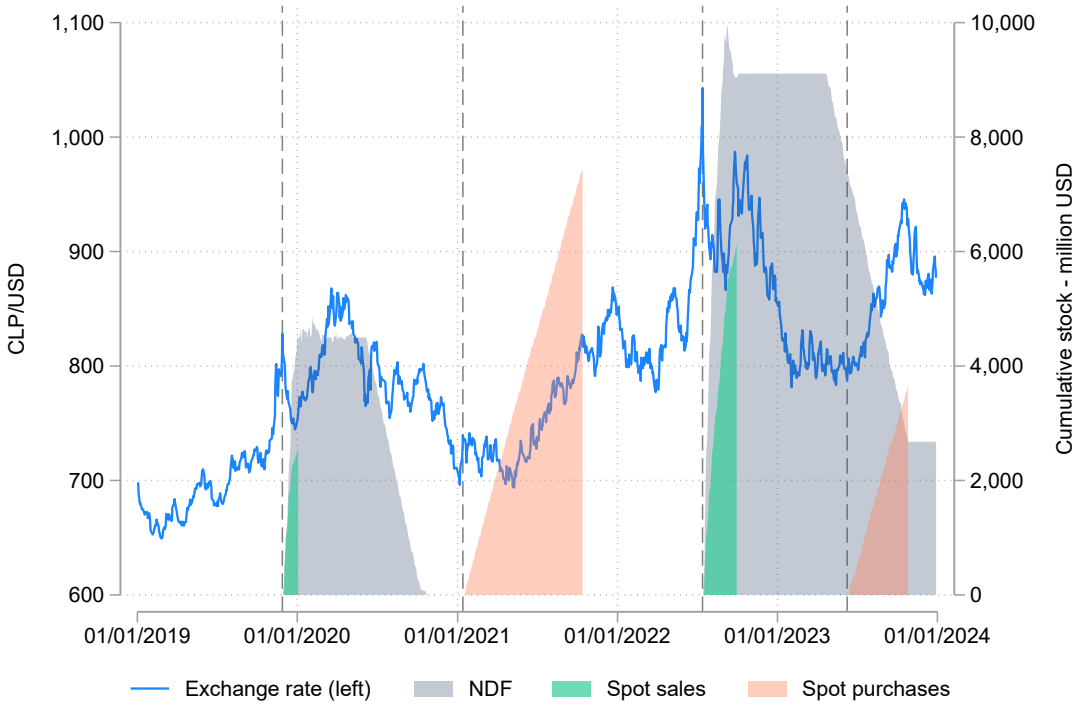
Regarding communication policy, the CBC announces the start of each intervention through public statements on its website a few days before the start of operations. These statements detail the purchase/sale modality (spot dollars and NDF instruments), the maximum trading amounts, and the start date of operations. Additionally, from the beginning of the intervention, the amounts to be traded for the next week are reported at the end of each week. It should be noted that the four intervention episodes were properly sterilized.

The details of each intervention are shown in Table 1. Regarding dollar purchase programs, the 2021 episode lasted for 193 days, while that of 2023 for only 98 days. In terms of the objective of these programs, the percentage of compliance with the total amount announced in purchases was 62% and 37%, respectively for the 2021 and 2023 interventions.[6] In both programs, an average of USD 40 million was purchased daily.

In the 2019 and 2022 interventions, maximum total amounts in the order of USD 20 billion, both in spot dollars and NDF instruments, were announced in each intervention.

[6]The 2023 intervention was suspended early at the CBC's October 2023 monetary policy meeting, due to "growing tensions in global financial markets" (CBC 2023).

FIGURE 1. Evolution of the exchange rate and cumulative daily intervention amounts (spot and NDF)



Note: dashed vertical lines represent the announcement of each FXI.

However, the amounts traded in the 2022 episode were more than double the 2019 FXI amounts (USD 6.1 versus USD 2.5 billion in the spot market and USD 9.9 versus USD 4.8 billion in NDF contracts). The duration of the 2022 intervention was also slightly more than double that of 2019.

Figure 1 shows the daily accumulated stock of the amounts of each intervention throughout the days in which the market was intervened, along with the evolution of the exchange rate (CLP per USD). The purchase of currencies was carried out gradually for the 2021 and 2023 interventions. Gradual sales are also observed in the 2019 and 2022 episodes, both in the spot market and in NDF contracts. Then, once the intervention in the spot market was completed, it is observed that the NDF contracts were constantly renewed in such a way as not to modify the stock reached in the intervention.

The total accumulated stock in NDF contracts in the 2019 intervention (USD 4.87 billion) was reduced at a constant rate of USD 40 million per day, from June to October 2020, until the CBC's selling position was closed. For the 2022 intervention, in April 2023 the total stock of USD 9.95 billion in NDF contracts began to be reduced at a constant rate of USD 50 million per day. However, in October 2023 this reduction stopped (CBC 2023), as of today there is still a stock of USD 2.67 billion.

3.2. Background of each FXI

This section provides a brief analysis of the exchange rate behavior in the months leading up to each FXI.

Figure 1 shows rapid and significant exchange rate depreciations in the weeks prior to the 2019 and 2022 intervention episodes. The exchange rate reached levels of CLP 828 in November 2019 and CLP 1,043 in July 2022, historical highs up to each date in the free-floating exchange rate system. The evolution of the exchange rate prior to the 2021 and 2023 interventions was different. An appreciation is observed before the 2021 episode, while prior to the 2023 episode a rather stable behavior of the exchange rate is observed.

These rapid exchange rate depreciation trends prior to the 2019 and 2022 interventions also led to increased volatility. Figure 2 shows the evolution of the daily return of the exchange rate (upper panel) and a measure of the volatility of these returns (lower panel).[7] An increase is observed in the volatility series prior to the 2019 and 2022 interventions, although this increase prior to the 2022 episode is larger. This is also reflected in a greater dispersion in the series of the daily return of the exchange rate, prior to the announcement of each of these interventions.

In response to these upward pressures on exchange rate volatility, the CBC intervened the FX market by selling currencies and acting as counterparty to banks and other financial actors. This was done to address the inability of these intermediaries to manage flows aimed at purchases (de Ramón 2020). The statements issued by the CBC announcing the beginning of these interventions refer to internal factors to explain the increase in volatility exhibited prior to the 2019 intervention (CBC 2019). While for the 2022 intervention, the statement mentions both internal and external sources as responsible for the excessive volatility (CBC 2022).

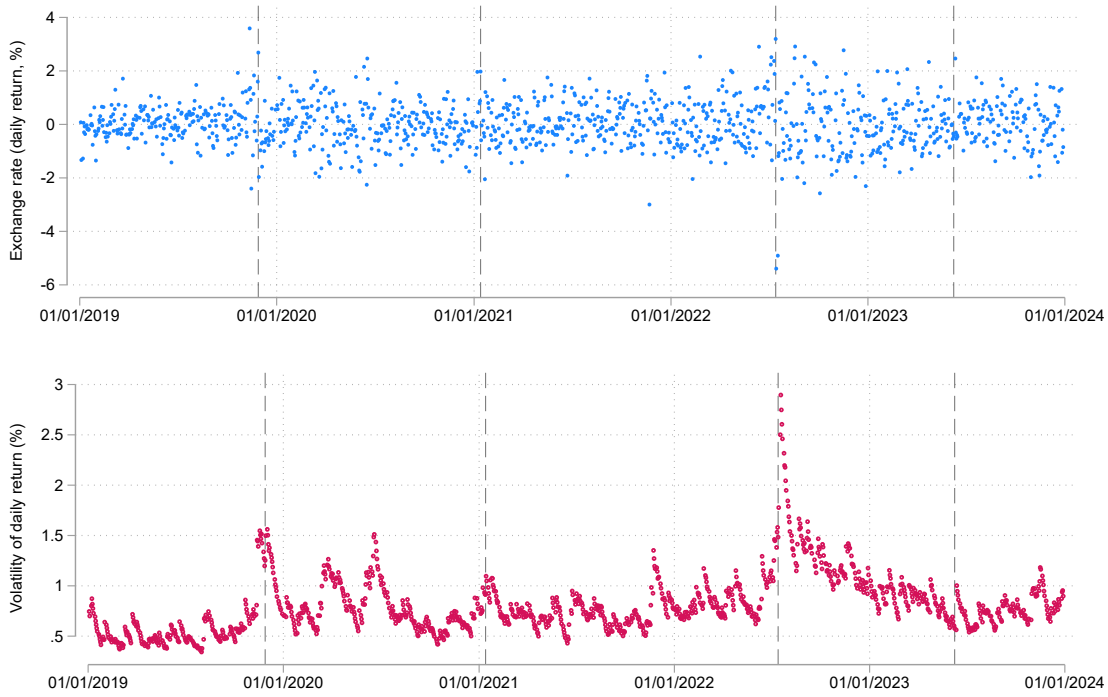
For the 2021 and 2023 FXI episodes, Figure 2 shows no significant increase in volatility before the start of each intervention. This is consistent with the motivation for this type of intervention: to increase international reserves, and not to correct volatility problems in the FX market. In the CBC's announcements for these interventions, the objective of increasing international reserves was based on the one hand, on replenishing the currencies sold in previous FXI (2019 and 2022, respectively for these 2021 and 2023 episodes), and on increasing international reserves as a fraction of GDP. This is important since the effectiveness of the 2021 and 2023 FXI is not related to the effect on the exchange rate or its volatility, but rather to fulfilling what was announced without generating

[7] Considering e_t as the (logarithm of the) Chilean nominal exchange rate on day t, daily return is defined as $\Delta e_t = e_t - e_{t-1}$. As for volatility, an exponentially weighted moving average (EWMA) model of daily return squares is used. The volatility of day t is defined as

$$\sigma_t^2 = 0.94\sigma_{t-1}^2 + (1 - 0.94)\left(\Delta e_t\right)^2 .$$

For further details, please refer to Section 4.2.

FIGURE 2. Daily return and volatility of the exchange rate



Note: volatility measured according to the EWMA model (parameter $\lambda = 0.94$). Dashed vertical lines represent the announcement of each FXI.

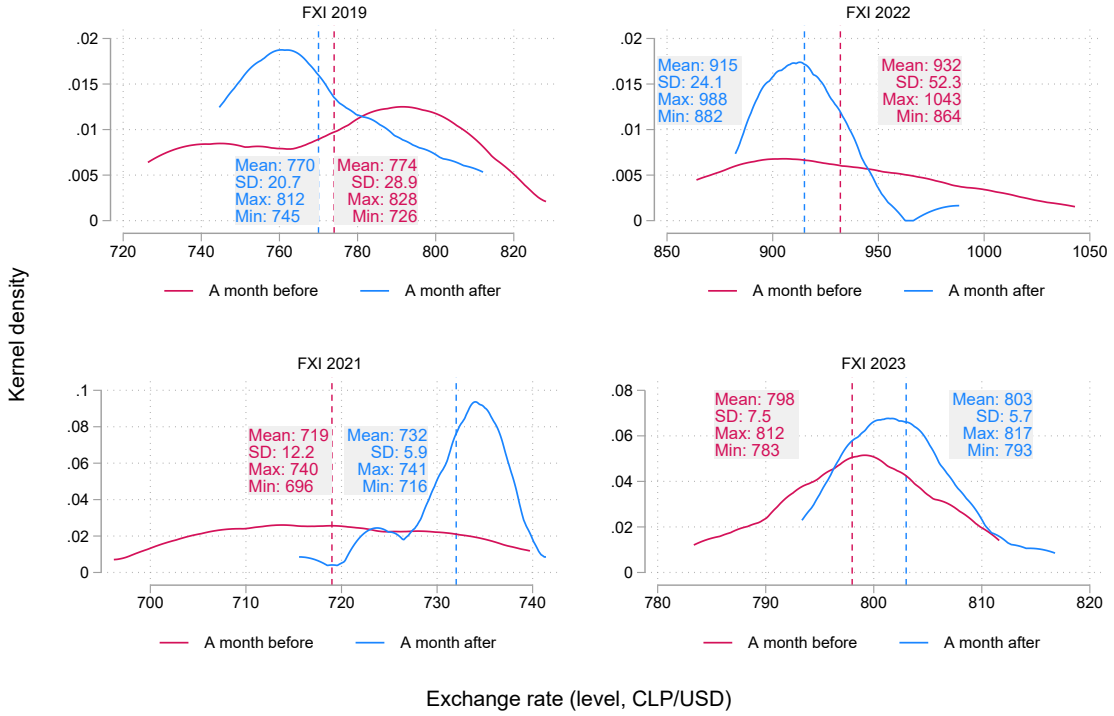
distortions in the FX market.

As a preliminary analysis of the effect of FXI on the exchange rate, one can compare different statistics in a one-month period around the start of each intervention. Figure 3 shows that for the 2019 and 2022 interventions, the mean of the exchange rate decreases in the month following the start of each FXI. While for the 2021 and 2023 interventions the opposite occurs, that is, the mean of the exchange rate increases in the month following the start of each dollar purchase program. Regarding volatility, whether measured by the standard deviation or by the range (max/min) of exchange rate observations, this decreased the month following the start of the intervention episodes of 2019, 2021 and 2022. For the 2023 dollar purchase program, a slight decrease was observed in the standard deviation, although the range does not appear to have decreased.[8]

The next section presents empirical strategies to estimate the effect of FXI on the exchange rate and its volatility, and thus evaluate the effectiveness of these interventions.

[8] Figure A1 in the Appendix A shows these densities but for the daily exchange rate return. The observations are similar.

FIGURE 3. Kernel density estimates of the exchange rate in a one-month period around the start of each intervention



Note: the red lines represent the previous month, while the blue lines represent the following month, relative to the start of each intervention.

4. Estimating FXI effects

In this section we estimate the effects of the four aforementioned FXI episodes on daily returns and exchange rate volatility.

To do this we use two econometric approaches. First, we present univariate models for the daily return and volatility of exchange rate. In these models we isolate the effect of interest by controlling for the fundamental variables of the exchange rate. We estimate these univariate models through local projections (Jordà 2005) to capture the dynamic effects of FXI.

Furthermore, using data from intraday transactions in the Chilean FX market, we analyse through event studies the effect of different announcements related to the 2022 intervention episode, published when the market was open.

In the second approach we estimate the effects of FXI using the Synthetic Difference-in-Differences (SDID) method (Arkhangelsky et al. 2021). In this approach, a synthetic control is constructed using a sample of exchange rates from other countries that did not intervene in their FX markets at the time when the CBC did so in the Chilean FX market.

We use this synthetic control as a counterfactual in order to estimate the effect of interest.

The primary econometric challenge is to address various identification problems that are prevalent in this context and that have been well-documented in the literature (Sarno and Taylor 2001; Menkhoff 2010; Blanchard, Adler, and de Carvalho Filho 2015; Fratzscher et al. 2019; Chamon, Garcia, and Souza 2017; Chamon et al. 2019). In the first approach, we rely on both high-frequency data (daily and intradaily) and control for fundamental variables to better identify the effects of interventions. This allows isolating the exchange rate movements that originate from these variables, thus avoiding erroneous attributions to FXI. Furthermore, with high-frequency data we can compare the almost instantaneous response of the exchange rate to different announcements related to the intervention episodes.

While the second approach is based on *parallel trends*, that is, in the absence of intervention the trend of the (daily return of the) Chilean exchange rate, or its volatility, is parallel to that of the control group. However, when the SDID method is used, the synthetic control group is constructed in such a way that the pre-intervention trends between both groups are weighted and matched as in the Synthetic Control (SC) methodology, and it is also controlled by time-invariant unobservable factors as in the Difference-in-Differences (DID) approach. These two characteristics help make the assumption of parallel trends more plausible (Arkhangelsky et al. 2021).

4.1. Data

Three data sets are used to estimate the effects of recent FXI episodes. In the first one, we use daily data on the Chilean nominal exchange rate and the amounts traded by the CBC in sales/purchases of spot dollars and NDF contracts during the intervention episodes. The set of *fundamental variables* that we use to explain the behavior of the exchange rate follows the model described in CBC (2020b, section 4.1.3). The sample starts on January 2, 2019, and ends on December 29, 2023. The data was extracted from the official website of the CBC and from Bloomberg.

The second data set consists of intraday transactions of the Chilean FX spot market for those days in which the CBC issued announcements when the market was open. In particular, we observe the amount negotiated and the exchange rate agreed upon in each transaction from May to October 2022, a period that fully covers the 2022 intervention. This data is obtained from the *DATATEC* platform.

The last data set is a panel of countries for which we look at each country's nominal exchange rate with respect to the USD and other financial variables. The panel begins on January 2, 2019, and ends on December 29, 2023. Data is obtained from Bloomberg.

4.2. Local Projections

As a first exercise to estimate the effects of FXI, the following models are presented for both daily return and volatility of the exchange rate.

Consider that e_t is the (logarithm of the) Chilean nominal exchange rate (CLP per USD) on day t, where an increase represents a depreciation. Additionally, consider that σ_t is a measure of daily volatility based on an exponentially weighted moving average (EWMA) model, $\sigma_t^2 = \lambda\sigma_{t-1}^2 + (1-\lambda)(\Delta e_{t-1})^2$, with a weight of $\lambda = 0.94$ (the factor suggested by *RiskMetrics* (Zumbach 2007)). The model specification for these variables, $y_t \in \{\Delta e_t, \Delta\sigma_t\}$,[9] and for intervention episodes $H = \{2019, 2021, 2022, 2023\}$ is as follow

$$y_{t+k} = \sum_{h\in H}\left(\beta_{h,k}A_{h,t} + \gamma_{h,k}FXI_{h,t} + \delta_{h,k}Spot_{h,t} + \phi_{h,k}NDF_{h,t}\right) + \alpha_{0,k} + \sum_{i=1}^{5}\alpha_{i,k}y_{t-i} + \sum_{i=0}^{6}\Gamma_{i,k}'X_{t-i} + u_{k,t}, \tag{1}$$

where the binary variables $FXI_{h,t}$, with $h \in H$, take the value 1 during the entire respective intervention period (from the beginning to the end of the spot transactions). The binary variables $A_{h,t}$ indicate the day after each intervention announcement, when operations had not yet began. $Spot_{h,t}$ and $NDF_{h,t}$ are the daily amounts traded (in million USD) by the CBC in spot dollars and NDF instruments, respectively, on day t for each episodes h. We set $\delta_{j,k} = \phi_{j,k} = 0$ for $j \in \{2021, 2023\}$ and for all horizon k since for the 2021 and 2023 interventions there was no sale of NDF instruments, and also daily purchases do not vary between days.

The vector X_t in Equation 1 includes linear and quadratic trends, and the following variables: broad dollar index, copper price, oil price, local and external (US) inflation (monthly variation of the consumer price index), government bonds credit default swaps spread, and the differential between US and Chilean one year interest rates. The number of lags for the dependent variable and controls (5 and 6 respectively), follows Jara and Piña (2023).

These models are estimated using the local projections method (Jordà 2005). The focus of local projections allows the estimation of impulse response functions (IRF) through simple estimation techniques based on regressions. Also, another advantage of using this technique is the non-dependence on invertibility restrictions (unlike in an autoregressive vector approach) as well as the robustness regarding possible specification errors (Jordà 2005; Plagborg-Møller and Wolf 2021). So, Equation 1 is estimated over horizons of $k \in \{0, 1, 2, \ldots, 30\}$ days, with standard errors robust to autocorrelation and heteroscedasticity problems (HAC matrix, Newey and West (1987)).

[9] Using different statistical tests, the null hypothesis of the presence of a unit root in both variables is rejected (see Table A1 in the Appendix A).

From Equation 1, the total effect of each intervention $h \in H$, in a horizon k, can be represented by $\tau_{h,k} = \beta_{h,k} + \gamma_{h,k} + \delta_{h,k} \cdot \overline{Spot}_h + \phi_{h,k} \cdot \overline{NDF}_h$, where $\overline{Spot}_h$ and $\overline{NDF}_h$ are the average daily amounts in spot dollars and NDF instruments, respectively, in each intervention $h \in \{2019, 2022\}$ (see Table 1).

Table 2 presents the results of the estimation of Equation 1 for the horizon $k = 0$. It can be observed that it is mainly the announcements that have the greatest effects, both on return and on volatility of the exchange rate. Moreover, for the 2019 and 2022 interventions the effects on the return of the exchange rate are in the expected direction since foreign currency was sold. However, because in the 2021 and 2023 episodes foreign currency was purchased, the expected effect would be in the direction of exchange rate depreciation. This only occurs in the 2023 episode, but not in the 2021 episode.

As for the magnitude of these effects, for the 2019 intervention the total effect is estimated at -2.5 percentage points (pp) of decrease in the daily return of the exchange rate. This effect is mainly influenced by the announcement effect (-2.3 pp). The additional effect of spot dollar and NDF sales is in the order of 2 and 0.7 pp of decrease in the return of the exchange rate per billion USD sold, respectively. However, these two additionally effects are not statistically different from each other, nor are they statistically different from zero at traditional confidence levels. In terms of volatility, the 2019 intervention announcement increased volatility by 0.2 pp, while in the full intervention period volatility was reduced by 0.04 pp. The total effect on volatility was an increase of 0.2 pp. This is not surprising, since volatility also increases when the exchange rate is reduced, and these results are at horizon $k = 0$.

The total effect of the 2022 intervention is in the order of 6.2 pp decrease in the daily return of the exchange rate. This effect is more than double that of the 2019 FXI. The announcement decreased return by 6 pp, while the sale of spot dollars and NDF had an additional effect of 0.004 and 0.2 pp decrease in return per billion USD sold. As in the 2019 intervention, these additional effects are neither statistically different from each other nor statistically different from zero. Volatility increased by 0.27 pp as a total effect. It was the announcement that contributed to 0.3 pp increase, as over the entire intervention period volatility decreased by 0.1 pp. While spot dollar sales did not have a significant effect on volatility, NDF sales reduced it by 0.3 pp for every billion USD sold, a significant result at the 10% level.

The results displayed in Table 2 show that the effect of the announcements over the return and volatility of exchange rate is one of the most robust ones. This is consistent with the evidence for Chile in the literature (Tapia and Tokman 2004; Fuentes et al. 2014; Larraín and Saravia 2019). The results also showcase the different channels through which FXI might impact the exchange rate. The significance of the effect of the announcements of both episodes can be considered as partial evidence in favour of the signalling channel

TABLE 2. Estimation of Equation 1 for the horizon $k = 0$

	$100 \cdot \Delta e_t$	$100 \cdot \Delta e_t$	$100 \cdot \Delta \sigma_t$	$100 \cdot \Delta \sigma_t$
A_{2019}	-1.981***	-2.284***	0.244***	0.218***
	(0.0309)	(0.121)	(0.00243)	(0.0100)
A_{2021}	-0.608***	-0.697***	0.182***	0.189***
	(0.0309)	(0.141)	(0.00243)	(0.0145)
A_{2022}	-5.407***	-6.043***	0.293***	0.298***
	(0.0309)	(0.221)	(0.00243)	(0.0214)
A_{2023}	2.449***	2.332***	-0.0148***	-0.00321
	(0.0309)	(0.118)	(0.00243)	(0.00999)
FXI_{2019}	0.288	0.101	-0.0294**	-0.0352**
	(0.362)	(0.284)	(0.0133)	(0.0142)
FXI_{2021}	0.0437	0.00191	-0.00325	-0.00513
	(0.0634)	(0.0598)	(0.00473)	(0.00572)
FXI_{2022}	0.966	0.362	-0.119	-0.141**
	(0.715)	(0.460)	(0.0861)	(0.0677)
FXI_{2023}	0.137*	0.125	-0.0000724	-0.00131
	(0.0797)	(0.0964)	(0.00733)	(0.0102)
$Spot_{2019}$	-0.00509**	-0.00241	0.0000107	0.000226
	(0.00213)	(0.00178)	(0.000155)	(0.000157)
NDF_{2019}	-0.00679	-0.000789	0.00153	0.00162*
	(0.00887)	(0.00697)	(0.00104)	(0.000837)
$Spot_{2022}$	-0.000113	-0.00000396	-0.0000438	-0.0000911
	(0.00148)	(0.00113)	(0.0000682)	(0.0000815)
NDF_{2022}	-0.00120	-0.00187	-0.000372	-0.000324*
	(0.00221)	(0.00214)	(0.000230)	(0.000189)
τ_{2019}	-2.297***	-2.464***	0.210***	0.197***
	(0.176)	(0.177)	(0.0106)	(0.0145)
τ_{2021}	-0.564***	-0.695***	0.178***	0.184***
	(0.0829)	(0.166)	(0.00632)	(0.0167)
τ_{2022}	-5.548***	-6.249***	0.259***	0.266***
	(0.242)	(0.294)	(0.0273)	(0.103)
τ_{2023}	2.587***	2.457***	-0.0149*	-0.00452
	(0.0961)	(0.175)	(0.00845)	(0.0164)
Mean dep. var.	0.0185	0.0208	0.000122	0.0000988
Tests (p-value)				
$Spot_{2019} = NDF_{2019}$	0.0959	0.322	0.785	0.139
$Spot_{2022} = NDF_{2022}$	0.603	0.904	0.114	0.0452
$Spot_{2019} = Spot_{2022}$	0.852	0.821	0.151	0.0971
$NDF_{2019} = NDF_{2022}$	0.682	0.446	0.171	0.257
Controls	✗	✓	✗	✓
T	1,245	1,239	1,244	1,239

Note: HAC standard errors in parentheses.

* $p < .10$, ** $p < .05$, *** $p < .01$.

since a considerable effect is produced merely by communicating the intervention, without yet resorting to the sale of currencies. [10] As mentioned in Section 3.1, the amounts traded in the 2022 intervention were almost double those of the 2019 one. According to one of the implications of the portfolio channel, the magnitude of the effect of FXI depends positively on the traded amounts. Thus, the larger magnitude of the 2022 effects is evidence in favour of the portfolio channel's prediction.

For the 2021 dollar purchase program, a total effect of -0.7 pp on the return of the exchange rate is estimated, and this effect is almost entirely due to the announcement (-0.7 pp). This program also had an effect on volatility, increasing it by 0.2 pp in total. The 2023 dollar purchase program had an opposite effect on the exchange rate, as it increased its daily return by 2.5 pp. The estimated effect on volatility is not significant at the 10% level.

In order to analyze the dynamic effects of these interventions, Figure 4 presents the estimation of the cumulative impulse response functions (CIRF) for each FXI. In the left panel of Figure 4, it can be observed that the 2019 and 2022 episodes have a negative effect on the daily return of the exchange rate, and this is maintained up to 30 days after the start of each intervention. It is also observed that the 2021 intervention shows no significant effects on the return, while the purchase of 2023 dollars significantly increased the return.

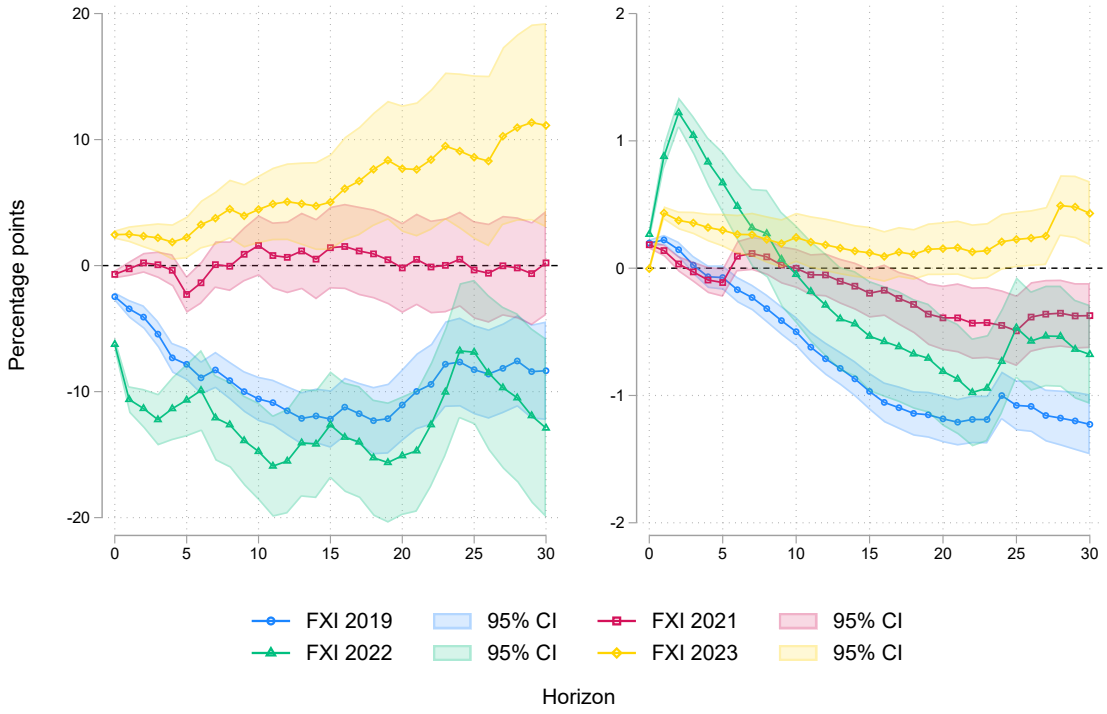
As mentioned above, the right panel of Figure 4 shows that all four intervention episodes increased volatility in the first few days after the start of operations. However, only the 2023 intervention shows a positive and persistent effect on volatility, as the 2019, 2021 and 2022 episodes show cumulative negative effects starting approximately 10 days after the start of each intervention. The effect of the 2022 intervention stands out, in which volatility increased by more than 1 pp, then decreased by around -0.5 pp. This is explained by the fact that the 2022 FXI appreciated the exchange rate the most in the first few days, and this brought with it an increase in volatility. However, after 30 days of intervention, volatility was reduced to a similar extent as in the 2019 intervention.

Figures 5 and 6 show the decomposition of the total effect of the left and right panels of Figure 4, respectively, between the effect of the announcements, the full intervention period, and spot and NDF dollar sales.[11] For the CIRF on the daily return of the exchange rate (Figure 5), it is observed that the announcement is the one that consistently contributes negatively in both the 2019 and 2022 episodes. Additionally, in the 2019 intervention, it is spot dollar sales that also contribute negatively, while in the 2022 FXI it is NDF sales. In both episodes, the entire intervention period contributes positively to the total effect.

[10] A more direct way to test this mechanism consist of studying the evolution of the expected monetary policy rate on the days following the announcement of each intervention. However, it is difficult to obtain daily expectation data.

[11] The estimated CIRFs for each of these components are shown in Appendix A (Figures A2, A3, A4, and A5).

FIGURE 4. Cumulative impulse response function (CIRF) of the total effect (Equation 1) on the daily return (left panel) and volatility (right panel) of the exchange rate

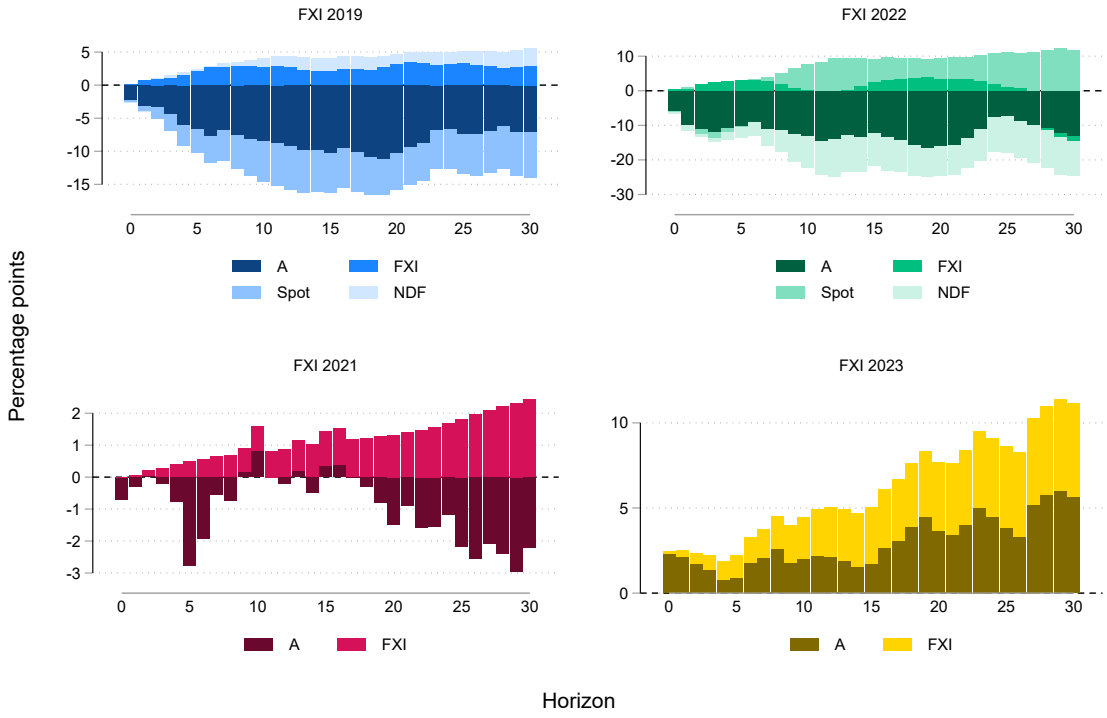


For the 2021 intervention, the negative effect of the announcement is offset by the positive effect of the entire period in which dollars were purchased. While for the 2023 episode, both the announcement and the entire intervention period contribute positively to the total effect.

The decomposition of the total effect on volatility (Figure 6) shows that for the 2019, 2021 and 2023 episodes, virtually all components contribute negative impacts to the total effect, within a 15-day horizon after the start of each intervention. For the 2023 intervention, the opposite is true, as both the announcement and the entire intervention period show an increase in volatility.

In summary, the 2019 and 2022 interventions appear to be effective in decreasing exchange rate volatility within the intervention period. The 2021 dollar purchase program does not appear to have a significant effect on the return of the exchange rate, but it does have a negative effect on volatility. Furthermore, let us recall that the compliance percentage of the total announced amount of dollar purchases was 62% (see Table 1). However, the 2023 dollar purchase program was characterized by positively affecting both the return and the volatility of the exchange rate. In addition, only 37% of the total announced was purchased, since this program was suspended early.

FIGURE 5. Decomposition of the cumulative impulse response function (CIRF) of the total effect (Equation 1) on daily return of the exchange rate



4.3. Intraday analysis for the 2022 FXI

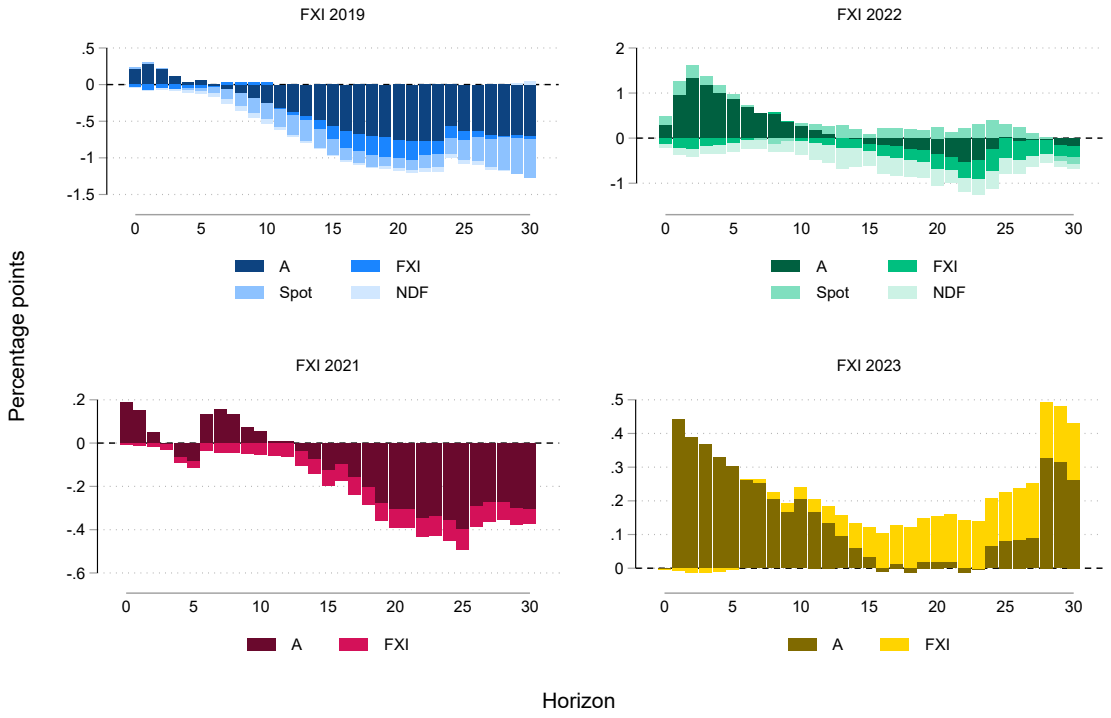
Normally, announcements regarding the start, operational details, and end of an FXI are uploaded to the CBC website when the market is practically closed. However, for the 2022 intervention, two announcements were made when the market was in operation. This section quantifies the effect of these announcements using an event study methodology.[12]

In the statement at the start of the 2022 intervention, it is mentioned that the amount, terms and conditions of the auctions for the following week will be reported at the end of each week. In total, there were eleven announcements about the amounts to be negotiated that were uploaded weekly on Fridays to the CBC website. Out of these eleven announcements, nine were uploaded after 2:00 p.m. local time, a time when the FX market presents very few operations (Fuentes et al. 2014).

Nevertheless, announcements for the first two weeks of this intervention were

[12]Event study models are commonly used for effectiveness evaluations of FXI (Contreras et al. 2013; Echavarría, Fernando Melo, and Villamizar 2014; Durán-Vanegas et al. 2016; Larraín and Saravia 2019). These types of models exploit the high frequency of data by comparing periods at the start of the intervention or at the announcement of it, so as to obtain an appropriate counterfactual by using observations prior to the intervention.

FIGURE 6. Decomposition of the cumulative impulse response function (CIRF) of the total effect (Equation 1) on volatility of the exchange rate

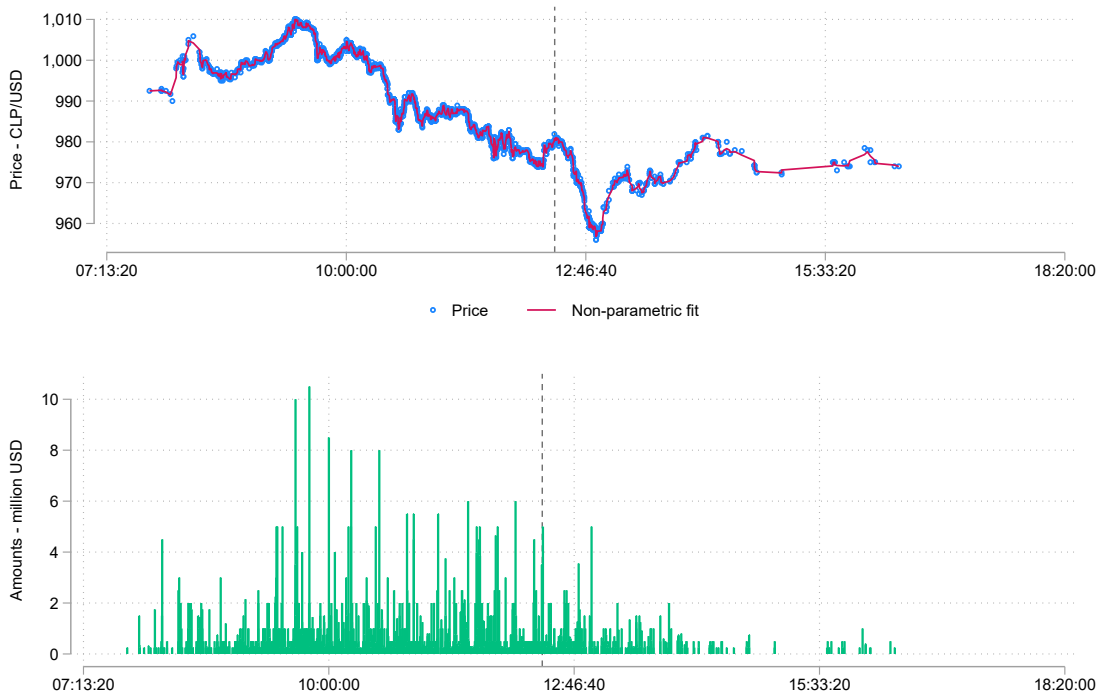


uploaded at 12:00 and 12:25 local time, respectively. The first of them was uploaded on July 15 and specified total sales in spot dollars for USD 1,000 million, and in NDF contracts for USD 2,500 million, for the first week of intervention. While the second announcement was uploaded on July 22 and specified total sales in spot dollars for USD 750 million, and in NDF contracts for USD 1,750 million.

Figures 7 and 8 show all transactions on July 15 and July 22, respectively. For each transaction we observe the price and amount traded, and the moment in which the transaction is made (hour-minute-second). Visually, it is observed in Figure 7 that after the announcement the appreciative tendency that predominated that day intensified for around 20 minutes. Furthermore, there is no significant increase in either the number of transactions or the amounts traded. For the announcement published on July 22, Figure 8 does not show a change in the exchange rate trend. An increase in transactions is observed, although not immediately, rather nearly 20 minutes later.

To quantify these effects, we simply compare the weighted average of the exchange rate in different windows around the announcement publication. For this, the following

FIGURE 7. FX transactions on July 15, 2022



Note: the dashed vertical lines represent the loading of the announcement on the web (12:25 local time).

equation is estimated

$$e_{t,s} = \beta_0 + \beta_1 A_t + u_{t,s}, \tag{2}$$

where $e_{t,s}$ is the (logarithm of the) price of the transaction s that occurred at instant t (hour-minute-second), A_t is a dummy variable that is activated from the moment in which each announcement is published on the web, and $u_{t,s}$ is an error term. The subscript s is only a correlative to indicate that more than one transaction can occur at the same time t. Equation 2 is estimated using OLS, weighting each observation by the amount associated with each transaction and with standard errors clustered by t. The estimate of the parameter β_1 provides the percentage difference between the weighted average transaction price one hour before the announcement and the weighted average transaction price x minutes after the announcement was made, with $x \in \{10, 20, 30, 40, 50, 60\}$.

The results are presented in Tables 3 and 4. In the case of the July 15 announcement, the exchange rate is observed to be 2.4% lower in post-announcement transactions. This effect starts to be observed after 20 minutes and becomes increasingly larger as time goes by. In the case of the July 22 announcement, the exchange rate is observed to have increased

FIGURE 8. FX transactions on July 22, 2022

Note: the dashed vertical lines represent the loading of the announcement on the web (12:00 local time).

by 1.6% after the announcement. This effect starts to be observed after 10 minutes and increases over time.

These effects are simply the weighted average comparison of the exchange rate and therefore may be affected by a daily trend. To understand the effect of these announcements on the return of the exchange rate, the data of these transactions are collapsed into minutes, calculating the weighted average price according to the amounts traded. In addition, only the time block from 8:00 a.m. to 2:00 p.m. remains in force. It is considered the time when the market has the greatest liquidity. In this way, a return per minute series can be constructed and the effect of announcements on this series estimated.

So, the effect of announcements on return per minute is estimated using two specifications: (i) parametric with linear trend and (ii) non-parametric. For the non-parametric specification, the Epanechnikov kernel is used for the trend and the Li-Racine kernel for the dummy variable indicative of the announcements (Racine and Li 2004; Cattaneo and Jansson 2018; Li and Racine 2023). In the parametric specification, all observations within a day are used to run the estimation, while in the non-parametric specification, the number of observations to be used is optimally chosen (see Cattaneo

TABLE 3. Estimation of Equation 2 for July 15, 2022

	$100 \cdot e_{t,s}$	$100 \cdot e_{t,s}$	$100 \cdot e_{t,s}$	$100 \cdot e_{t,s}$	$100 \cdot e_{t,s}$	$100 \cdot e_{t,s}$	$100 \cdot e_{t,s}$
A	-2.420***	0.00389	-0.433***	-1.125***	-1.191***	-1.170***	-1.157***
	(0.0805)	(0.0300)	(0.0697)	(0.0986)	(0.0965)	(0.0899)	(0.0849)
_cons	690.1***	688.7***	688.7***	688.7***	688.7***	688.7***	688.7***
	(0.0490)	(0.0225)	(0.0225)	(0.0225)	(0.0225)	(0.0225)	(0.0225)
Window	All day	10 min.	20 min.	30 min.	40 min.	50 min.	60 min.
T	2,627	593	675	799	819	847	869

Note: clustered standard errors in parentheses.
* $p < .10$, ** $p < .05$, *** $p < .01$

TABLE 4. Estimation of Equation 2 for July 22, 2022

	$100 \cdot e_{t,s}$	$100 \cdot e_{t,s}$	$100 \cdot e_{t,s}$	$100 \cdot e_{t,s}$	$100 \cdot e_{t,s}$	$100 \cdot e_{t,s}$	$100 \cdot e_{t,s}$
A	1.588***	0.992***	0.957***	0.894***	0.931***	1.104***	1.191***
	(0.0489)	(0.0463)	(0.0430)	(0.0364)	(0.0374)	(0.0572)	(0.0587)
_cons	683.2***	683.4***	683.4***	683.4***	683.4***	683.4***	683.4***
	(0.0146)	(0.0347)	(0.0347)	(0.0347)	(0.0347)	(0.0347)	(0.0347)
Window	All day	10 min.	20 min.	30 min.	40 min.	50 min.	60 min.
T	2,158	647	720	812	890	982	1,040

Note: clustered standard errors in parentheses.
* $p < .10$, ** $p < .05$, *** $p < .01$

and Jansson (2018)).

Table 5 shows the results of these two specifications. It is observed that only the announcement of July 15 has a significant effect on the returns series. The magnitude of this effect is -0.56 pp according to the parametric specification and -0.09 pp according to the non-parametric specification. For the announcement of July 22, no significant effects are found. These results can also be observed graphically in Figures A6 and A7 in the Appendix A.

Although both announcements contained practically the same information, only the one on July 15 caused a further depreciation of the exchange rate. This is explained by the fact that on July 15, one day after the announcement of the intervention, the market was still waiting to see what daily amounts would be traded in the first week of intervention. And the announcement on that day made this clear. On the other hand, on July 22 there was already information on the daily amounts traded that week, and the announcement on that day did not surprise with major changes in the conditions of sale, but simply reduced the amounts to be traded.

TABLE 5. Estimation of the July 15 and 22 announcements effect on returns per minute, with parametric and non-parametric specifications

	July 15, 2022		July 22, 2022	
	$100 \cdot \Delta e_t$	$100 \cdot \Delta e_t$	$100 \cdot \Delta e_t$	$100 \cdot \Delta e_t$
trend	-0.0000775	0.00114***	0.000110	-0.0000352
	(0.000119)	(0.000424)	(0.000103)	(0.000339)
A	-0.557***	-0.0895**	0.0101	-0.00268
	(0.170)	(0.0359)	(0.0870)	(0.0309)
$A \cdot$ trend	0.00204***		-0.0000530	
	(0.000610)		(0.000373)	
Specification	Parametric	Non-parametric	Parametric	Non-parametric
T	315	151	291	147

Note: HAC standard errors in parentheses. Parametric specification considers a linear trend and the interaction with the dummy of interest. For non-parametric specification, the Epanechnikov kernel is used for the trend, and the Li-Racine kernel for the dummy of interest (Racine and Li 2004; Cattaneo and Jansson 2018; Li and Racine 2023).

* $p < .10$, ** $p < .05$, *** $p < .01$

4.4. Synthetic Difference-in-Differences Approach

In this section we use the Synthetic Difference-in-Differences (SDID) method to estimate the effects of FXI.

The idea of the SDID is to construct an adequate counterfactual to compare it with the evolution of the daily return (or volatility) of the Chilean exchange rate days after each intervention. In the construction of this counterfactual, those countries similar to Chile in terms of their observable variables before the intervention are weighted more. Likewise, those pre-intervention periods that are more similar to those post-intervention also receive greater weight. Thus, as these weights differ across countries and sample periods (days), the estimated Average Treatment effect on the Treated (ATT) is local (Arkhangelsky et al. 2021).

Consider a (balanced) panel of N countries and T time periods. Let $\Delta e_{i,t}$ be the daily return of the nominal exchange rate of country i relative to the USD on day t, and let $\sigma_{i,t}$ be the EWMA volatility of the exchange rate of country i on day t. Denote by $FXI_{i,t}$ the binary variable that indicates the exposure of treatment (e.g. an FXI) of a country i on day t. The SDID consists of the following. First, determine two types of weights: (i) unit-weights $\hat{\eta}_i$ that balance pre-intervention trends in the daily return (or volatility) of the exchange rate of control countries (those did not intervene) with those of the treated countries (those did intervene); (ii) time-weights $\hat{\mu}_t$ that balance pre- and post-intervention time periods.

And then, solve the following problem for each variable $y_{i,t} \in \{\Delta e_{i,t}, \Delta \sigma_{i,t}\}$

$$\min_{\{\alpha,\tau,\gamma_i,\delta_i\}} \sum_{n=1}^{N} \sum_{t=1}^{T} \left(y_{i,t} - \alpha - \tau \cdot FXI_{i,t} - \gamma_i - \delta_t - \Gamma' X_{i,t} \right) \hat{\eta}_i \cdot \hat{\mu}_t, \tag{3}$$

where γ_i and δ_t are country and time fixed effects, respectively, and $X_{i,t}$ is a vector of observable variables that includes the 1-year interest rate spread with respect to the US, the government bond credit default swap spread, and monthly inflation, for country i in day t. The way that the SDID finds the weights $(\hat{\eta}_i, \hat{\mu}_t)$ follows Arkhangelsky et al. (2019, section 2.1).

Nominal exchange rates (units of local currency per USD) of the following countries are part of the panel: Australia, Brazil, Chile, Colombia, Czech Republic, Indonesia, Israel, Korea, Mexico, Malaysia, New Zealand, Peru, Philippines, Poland, Russia, Thailand and Turkey.[13] The Figures A8, A9, A10 and A11 in Appendix A show the evolution of the daily return of the exchange rate and the daily variation in volatility for each country.

We solve Problem 3 separately for each intervention episode, setting a window of 60 days before each announcement, until the end of spot transactions.[14] Standard errors are calculated using the placebo method (see Arkhangelsky et al. (2021) for more details).

Table 6 presents the results of the estimation of the effect of each FXI on the daily exchange rate return. It is observed that, once the controls are included in the estimation, only the 2019 and 2022 FXI have a significant and negative effect on the daily exchange rate return. The magnitudes are -0.4 pp and -0.3 pp of decrease in the daily return in the 2019 and 2022 episodes, respectively.

The estimate of the effect on volatility is shown in Table 7. All interventions had a significant effect on volatility. In particular, the 2019 and 2022 interventions reduced volatility by 0.08 and 0.03 pp, respectively. The 2021 intervention also reduced volatility, although to a lesser extent, by 0.01 pp. In contrast, a significant increase in volatility is observed in the 2023 dollar purchase program, of magnitude 0.02 pp.

These effects are consistent with those presented in Section 4.2. However, these results show that the effect on the daily return of the exchange rate is larger in the 2019 intervention than in the 2022 one. As we know from Section 4.2, the announcement effect is the largest, but in the estimations of this section it is not possible to separate these effects.

However, Figures 9 and 10 show the estimation of the parameter of interest (τ in Problem 3) by moving the number of days after the start of each FXI used in the estimation. Therefore, estimates using fewer days after the start of each FXI could be considered more

[13] Most of these countries are those considered by Chamon, Garcia, and Souza (2017) in its exercise of evaluating FXI episodes in Brazil, using the synthetic control method.

[14] To do this we use the program proposed by Clarke et al. (2023), *SDID*, in *Stata*.

TABLE 6. Estimation of the parameter τ of Problem 3 for the daily return of the exchange rate

	$100 \cdot \Delta e_{i,t}$	$100 \cdot \Delta e_{i,t}$	$100 \cdot \Delta e_{i,t}$	$100 \cdot \Delta e_{i,t}$	$100 \cdot \Delta e_{i,t}$	$100 \cdot \Delta e_{i,t}$	$100 \cdot \Delta e_{i,t}$	$100 \cdot \Delta e_{i,t}$
FXI_{2019}	-0.319***	-0.432***						
	(0.0161)	(0.104)						
FXI_{2021}			-0.0574**	-0.0307				
			(0.0236)	(0.0354)				
FXI_{2022}					-0.539***	-0.329***		
					(0.0797)	(0.0884)		
FXI_{2023}							-0.00298	0.106
							(0.0331)	(0.121)
Mean dep. var. (%)								
All countries	-0.0340	-0.0328	0.00108	0.00108	0.0877	0.120	0.0348	0.0269
CHL	0.0617	0.0617	0.00909	0.00909	0.142	0.142	0.0832	0.0832
Controls	✗	✓	✗	✓	✗	✓	✗	✓
$N \cdot T$	1,411	913	4,216	2,728	1,921	1,243	2,601	1,683

Note: standard errors in parentheses (placebo method). The full sample considers the following countries: AUS, BRA, CHL, COL, CZE, IDN, ISR, KOR, MEX, MYS, NZL, PER, PHL, POL, RUS, THA and TUR. The sample with controls is restricted to: AUS, BRA, CHL, COL, IDN, KOR, MEX, MYS, NZL, POL and TUR.
* $p < .10$, ** $p < .05$, *** $p < .01$.

informative about the effect of the announcements. In Figure 9, it can be observed that the 2022 intervention reduced the return by about 5 pp one day after the intervention started. While this effect in the 2019 intervention is about 2 pp of the return decline. As the estimation window increases, the effect decreases in magnitude, but remains significantly below 0 up to 30 days after the start of each intervention. In the 2019 intervention, the decrease in magnitude is smaller than that of the 2022 intervention. This explains why the estimated coefficient in Table 6 for the 2019 FXI is larger (in absolute value) than that of the 2022 FXI.

As for the effect on volatility, it can be seen in Figure 10 that in the 2022 intervention, volatility increased by almost 0.5 pp on the day this intervention began. While in the 2019 intervention this increase was more moderate, in the order of 0.1 pp. The negative effect on volatility starts to be observed when the estimation window reaches 7 days after the 2019 FXI announcement. For the 2022 FXI, at least 15 days after the announcement must be included in the estimation window to observe negative effects.

For the 2021 and 2023 dollar purchase programs, Figures 9 and 10 show that the initial effect on the return of the exchange rate was a decrease of less than 1 pp for the 2021 program, and an increase of almost 2 pp for the 2023 program. However, these effects become insignificant as the estimation window increases. The initial effect on volatility is also larger in the 2023 program than in the 2021 program (0.3 versus 0.1 pp, respectively), but these effects also disappear as the estimation window increases.

TABLE 7. Estimation of the parameter τ of Problem 3 for the volatility of the exchange rate

	$100 \cdot \Delta\sigma_{i,t}$	$100 \cdot \Delta\sigma_{i,t}$	$100 \cdot \Delta\sigma_{i,t}$	$100 \cdot \Delta\sigma_{i,t}$	$100 \cdot \Delta\sigma_{i,t}$	$100 \cdot \Delta\sigma_{i,t}$	$100 \cdot \Delta\sigma_{i,t}$	$100 \cdot \Delta\sigma_{i,t}$
FXI_{2019}	-0.0380***	-0.0756***						
	(0.00297)	(0.00437)						
FXI_{2021}			-0.0180**	-0.0117***				
			(0.00765)	(0.00150)				
FXI_{2022}					-0.0311***	-0.0256***		
					(0.00955)	(0.00426)		
FXI_{2023}							0.0198**	0.0187***
							(0.00822)	(0.00586)
Mean dep. var. (%)								
All countries	-0.00119	-0.00138	-0.000422	-0.000408	0.00102	0.00124	-0.000695	-0.000638
CHL	0.00253	0.00253	0.00102	0.00102	0.00338	0.00338	-0.000556	-0.000556
Controls	✗	✓	✗	✓	✗	✓	✗	✓
$N \cdot T$	1,411	913	4,216	2,728	1,921	1,243	2,601	1,683

Note: standard errors in parentheses (placebo method). The full sample considers the following countries: AUS, BRA, CHL, COL, CZE, IDN, ISR, KOR, MEX, MYS, NZL, PER, PHL, POL, RUS, THA and TUR. The sample with controls is restricted to: AUS, BRA, CHL, COL, IDN, KOR, MEX, MYS, NZL, POL and TUR.

* $p < .10$, ** $p < .05$, *** $p < .01$.

5. Discussion

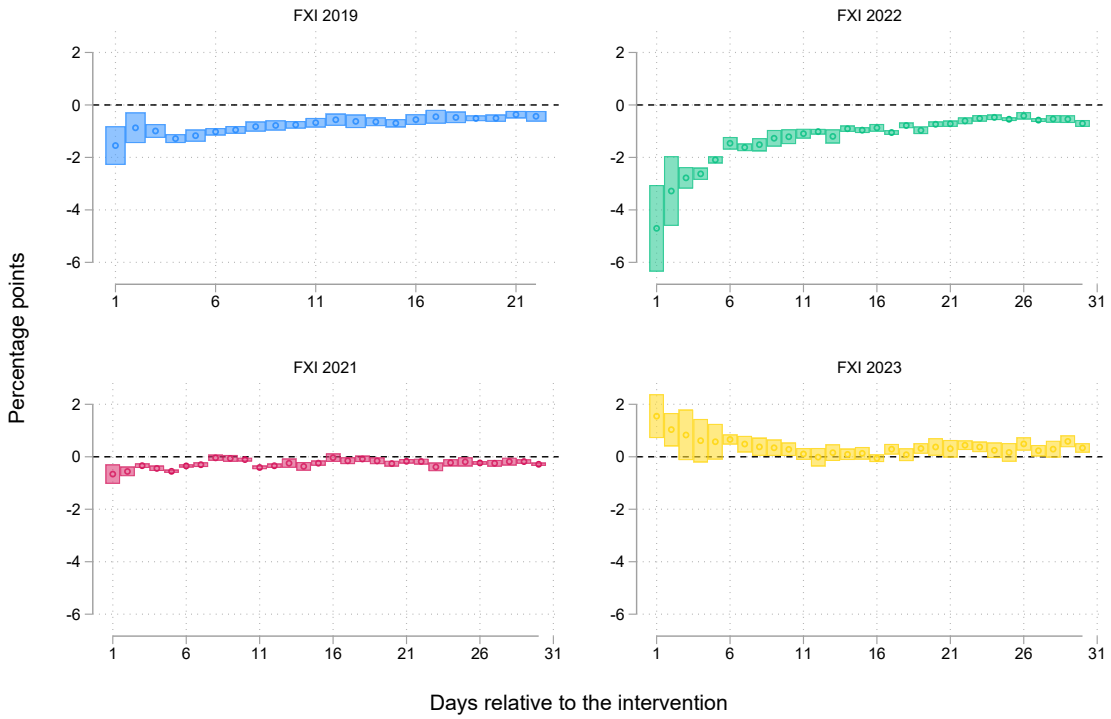
The results of the previous sections show that the 2019 and 2022 interventions were effective in terms of their objective: to correct exchange rate volatility problems. Both interventions significantly and persistently reduced exchange rate volatility (and also its daily return).

This occurred because the CBC acted as counterparty, both in the spot and forward markets, to the pressures aimed at purchasing foreign currencies that other financial institutions could not compensate.

Furthermore, in both episodes the normal functioning of the FX market could be restored without selling the maximum amounts announced. For the 2019 FXI, only 26% in spot dollars and 49% in NDF contracts were sold, compared to the total announced. In the 2022 FXI these percentages are 62% and 99%, respectively.

However, interventions in which foreign currency is sold have a direct cost on international reserves. Therefore, reducing the costs of these interventions without sacrificing their effectiveness would be an efficiency gain for Central Banks. Although the evidence presented in this article does not allow us to completely separate the effect of dollar spot sales from NDF contract sales, regarding the additional effect of these sales, the results show that it is not possible to reject the null hypothesis posed by equal effects. As mentioned in Section 4.2, it is only possible to reject this hypothesis when the effect on volatility is estimated (column (4) of Table 2). Furthermore, it is also not possible to

FIGURE 9. SDID effect on daily return of the exchange rate



Note: bars represent 95% confidence intervals (placebo method). The estimation considers the control variables.

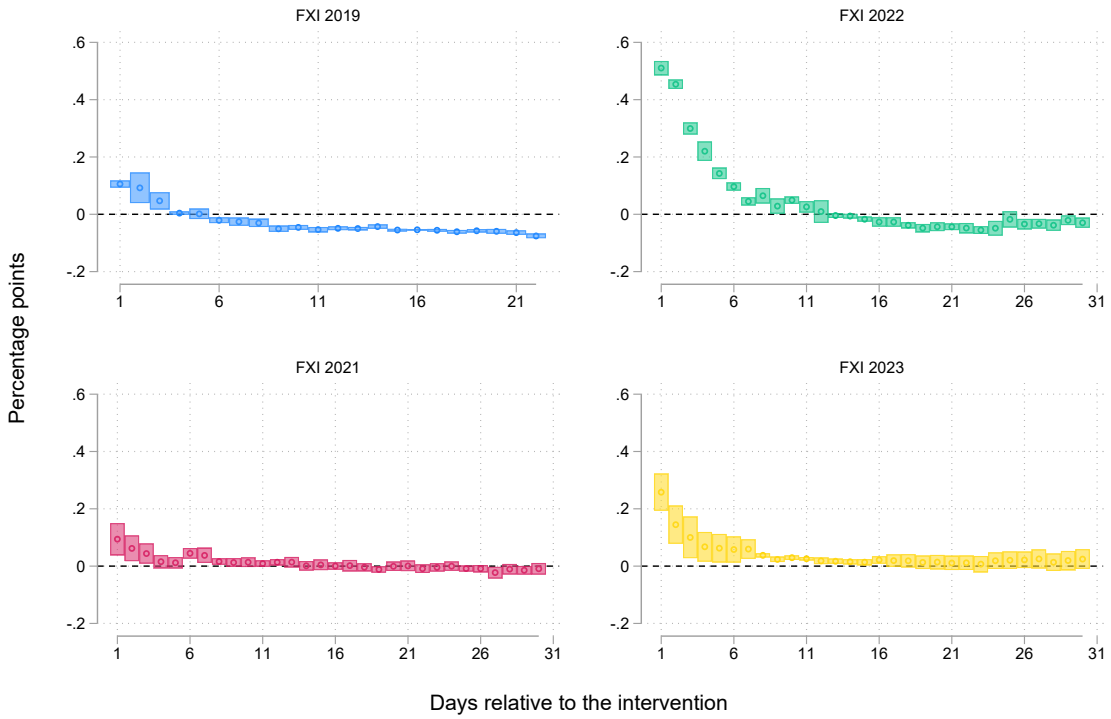
reject the null hypothesis that these additional effects of sales of spot dollars and NDF contracts were different between the 2019 and 2022 FXI. This result is in line with an incipient literature, which shows both theoretically and empirically similar effects for both instruments (see Nedeljkovic and Saborowski (2019); Walker (2019)).

This opens an interesting question about the extent to which spot dollar sales can be replaced by NDF sales, with the aim of reducing losses in international reserves without affecting the objective of a specific FXI. The results of this article suggest that both instruments appear to be equally effective, although each intervention episode may have different roots depending on whether the distortions come from the spot or forward market.

Regarding the dollar purchase programs for 2021 and 2023, the results of the previous sections show that in 2021 a high percentage of what was announced could be fulfilled (62%) without causing effects on the return of the exchange rate or its volatility. But for the 2023 program the opposite happened. Only 37% of the announced purchases were achieved and this program also had a depreciating effect on the return of the exchange rate.

To understand this difference, Figure 11 shows the evolution of the net position in

FIGURE 10. SDID effect on volatility of the exchange rate



Note: bars represent 95% confidence intervals (placebo method). The estimation considers the control variables.

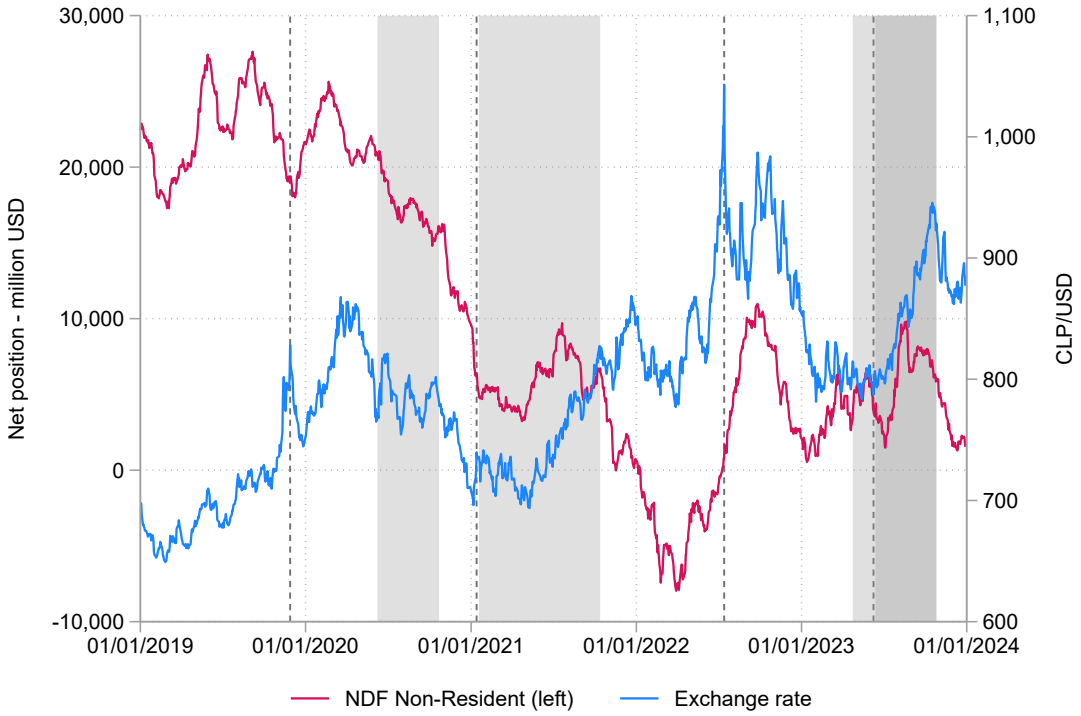
foreign currency derivatives NDF by non-resident agents (positive values reflect a net buying position). Prior to the 2021 intervention, it is observed that this net position had been falling, stabilizing at around USD 5 billion after the start of the intervention. On the other hand, for the 2023 intervention, although the net position remained at similar values (UDS 4.5 billion), it is observed that after the start of the intervention this increases to almost USD 10 billion. So, the pressures on the exchange rate were greater.

Although the flows that determine these positions are endogenous enough to be included in the estimates, it is likely that part of them respond to the interest rate differential between Chile and the US.[15] This is shown in Figure 12, where a marked negative relationship is observed between these positions and the 1-year interest rate differential.

On the other hand, the 2021 intervention occurred after the CBC finished closing its 2019 FXI NDF selling position. On the contrary, the liquidation of the 2022 FXI selling position had begun only two months before the start of the 2023 dollar purchase program. Therefore, the pressures on the exchange rate came from the purchase of dollars, from the bets against the Chilean peso of non-residents in the forward market, and in addition to

[15] For example, those motivated by carry trade operations in derivatives.

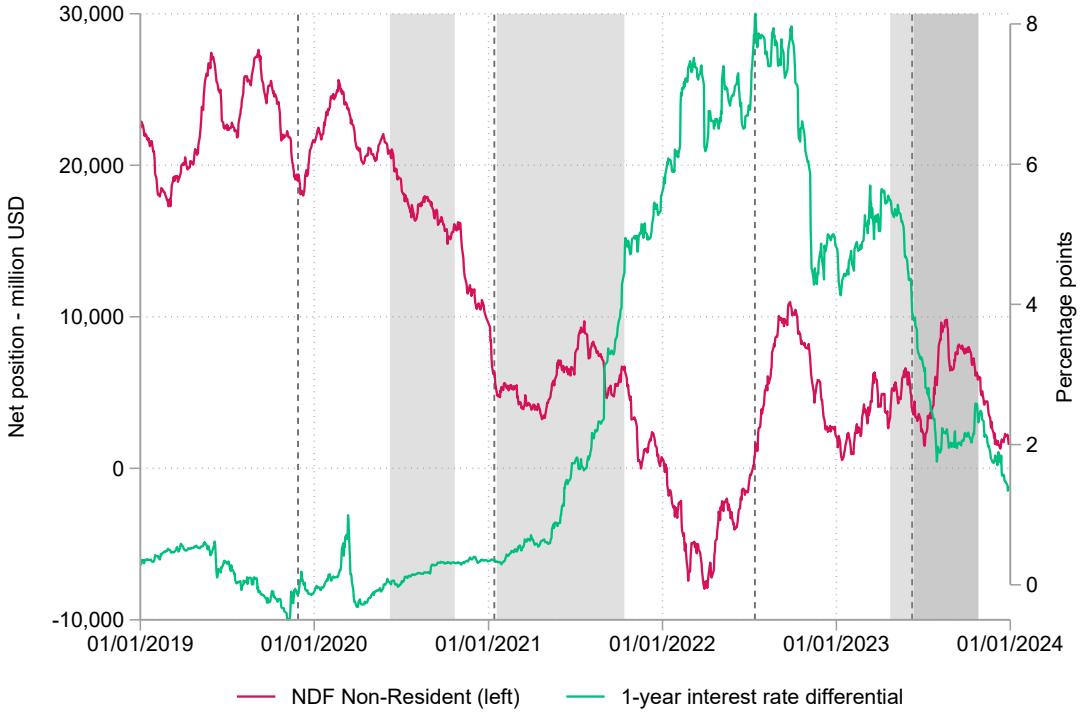
FIGURE 11. Net FX derivatives (NDF) position by non-residents and exchange rate



Note: vertical dashed lines show the beginning of each FXI. Shaded areas show the periods of liquidation of selling positions in NDF by the CBC, and the periods of spot FX purchases (2021 and 2023).

the dismantling of the selling position in NDF of the FXI of 2022. It was in this context that the decision was made to suspend both the dollar purchase program and the disarmament of the NDF contracts (CBC 2023).

FIGURE 12. Net FX derivatives (NDF) position by non-residents and 1-year interest rate differential between Chile and US



Note: vertical dashed lines show the beginning of each FXI. Shaded areas show the periods of liquidation of selling positions in NDF by the CBC, and the periods of spot FX purchases (2021 and 2023).

6. Final comments

In this paper we empirically evaluated the effectiveness of the last four FXI carried out by the CBC. Using daily and intraday exchange rate frequency data, the effect of these FXI on exchange rate volatility was estimated using local projections, event study, and synthetic difference-in-differences methods.

The results show a significant effect in the direction of reducing exchange rate volatility, both in the 2019 and 2022 FXI. The 2021 dollar purchase program had no effect on the exchange rate and a high percentage of the announced purchases (62%) were achieved. But the 2023 program only achieved 37% of the announced purchases.

While the evidence presented supports the implications of different mechanisms, such as the signalling or portfolio channel, it is the announcements of the start of the interventions that have the greatest effects.

The results analyzed in this article contribute to the literature on the effectiveness of FXI by highlighting evidence from the Chilean context, characterized by a free-floating

regime and an independent monetary policy within an inflation targeting framework.

Lastly, a relevant finding presented in this article refers to the inability to reject the null hypothesis that the effect of the amounts of the intervention in spot dollars is different to that of the NDF contracts in the same intervention episode. This finding is quite interesting because there is a tendency to intervene both markets simultaneously in a singular intervention episode.

Thus, this result suggests the market could possibly be intervened only with NDF contracts or rather, in a higher proportion of these, while maintaining the effectiveness documented in this article and minimizing the cost associated to the sale of international reserves of Central Banks. Hence, studying this result in depth should be the topic of future research.

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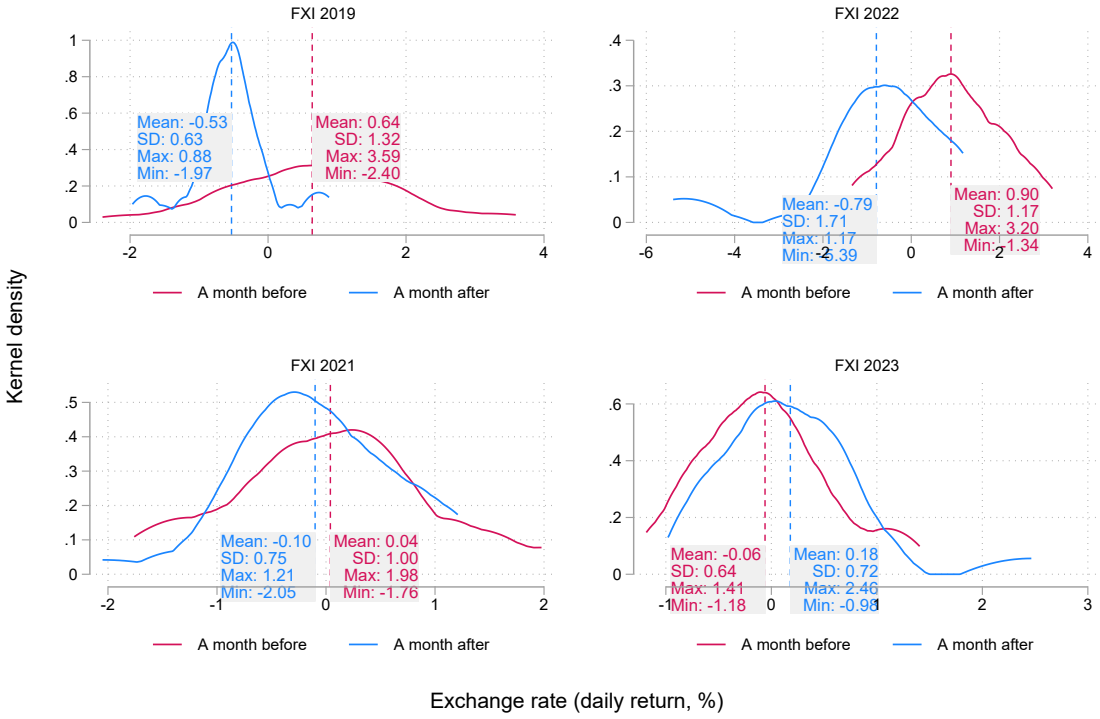
Appendix A. Other figures and tables

FIGURE A1. Kernel density estimates of daily return of the exchange rate in a one-month period around the start of each intervention



Note: the red lines represent the previous month, while the blue lines represent the following month, relative to the start of each intervention.

TABLE A1. Unit root test for daily return and volatility of the exchange rate

Test	Null hypothesis	Test statistic		Critical values		
		Daily return (Δe_t)	Volatility ($\Delta\sigma_t$)	1%	5%	10%
Dickey-Fuller	Random walk w/o drift	-14.987	-15.081	-3.43	-2.86	-2.57
	Random walk w/drift	-14.987	-15.081	-2.329	-1.646	-1.282
	Random walk w/trend	-14.983	-15.075	-3.96	-3.14	-3.12
Dickey-Fuller (GLS)	Random walk w/trend	-23.879 (lag 1)	-22.712 (lag 1)	-3.48	-2.849	-2.561
		-19.962 (lag 2)	-17.674 (lag 2)	-3.48	-2.850	-2.562
		-17.103 (lag 3)	-14.927 (lag 3)	-3.48	-2.851	-2.563
		-15.268 (lag 4)	-13.581 (lag 4)	-3.48	-2.852	-2.564
		-14.484 (lag 5)	-11.660 (lag 5)	-3.48	-2.853	-2.565
Phillips-Perron	Random walk	-960.908 (rho)	-1,061.459 (rho)	-20.7	-14.1	-11.3
		-29.111 (tau)	-32.123 (tau)	-3.43	-2.86	-2.57
	Random walk w/trend	-960.881 (rho)	-1,061.46 (rho)	-29.5	-21.8	-18.3
		-29.099 (tau)	-32.109 (tau)	-3.96	-3.41	-3.12

Note: these test are based on Dickey and Fuller (1979), Phillips and Perron (1988) and Cheung and Lai (1995).

FIGURE A2. CIRF based in Equation 1 for daily return of the exchange rate, FXI 2019 and 2022

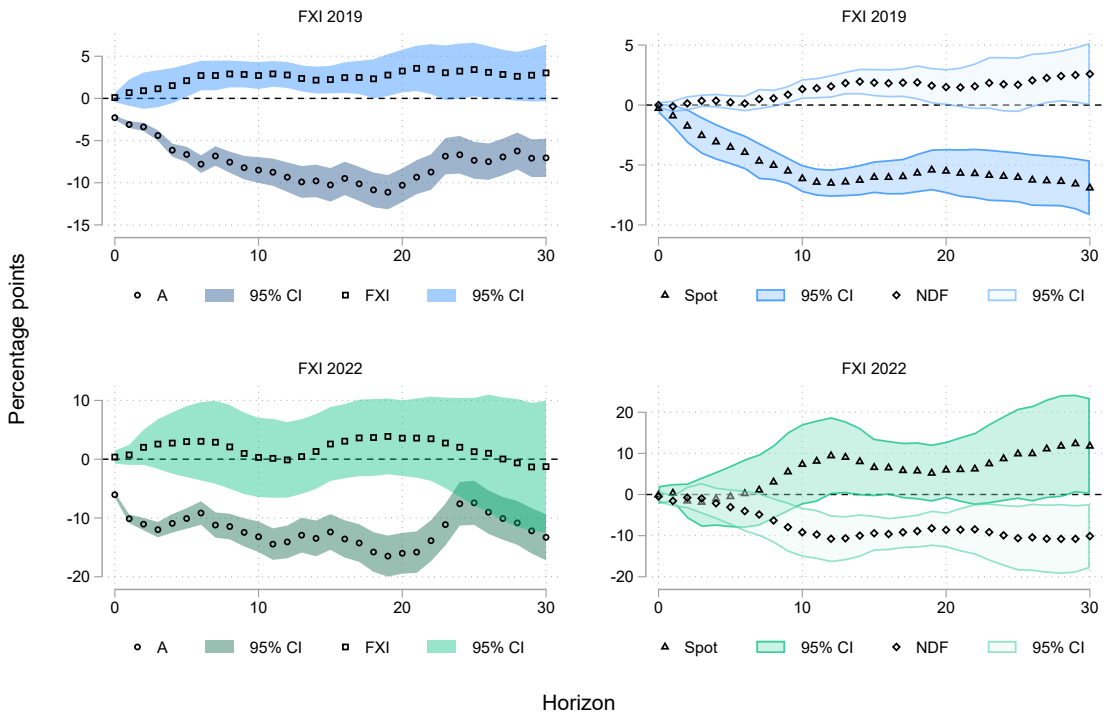


FIGURE A3. CIRF based in Equation 1 for daily return of the exchange rate, FXI 2021 and 2023

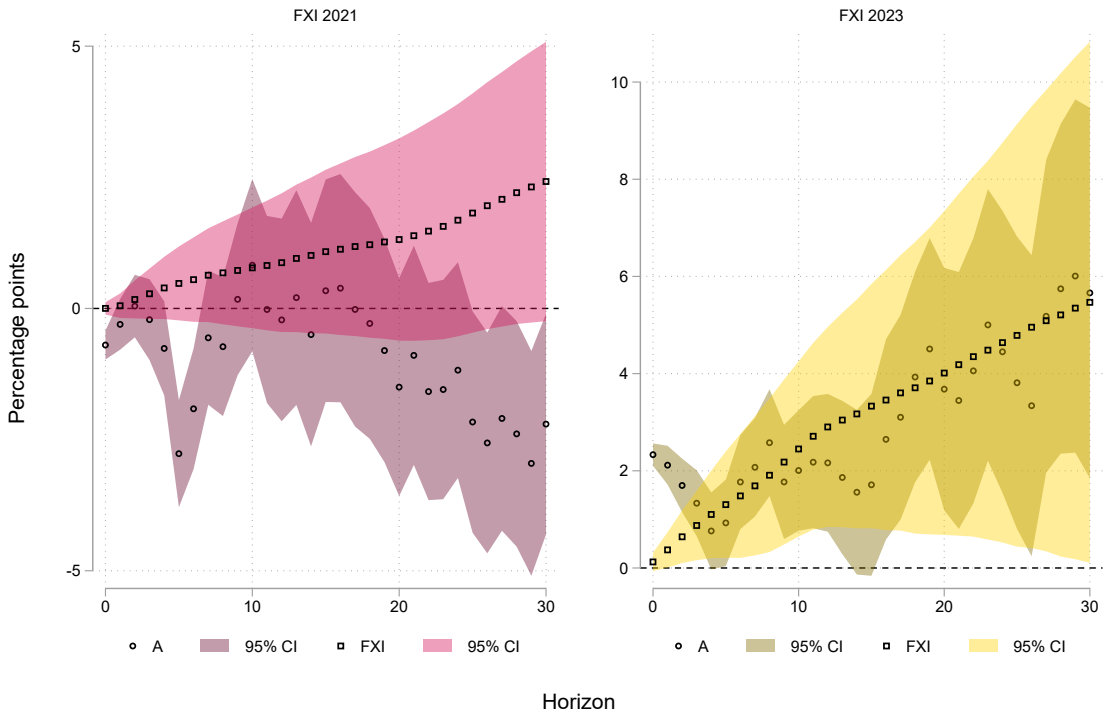


FIGURE A4. CIRF based in Equation 1 for volatility of the exchange rate, FXI 2019 and 2022

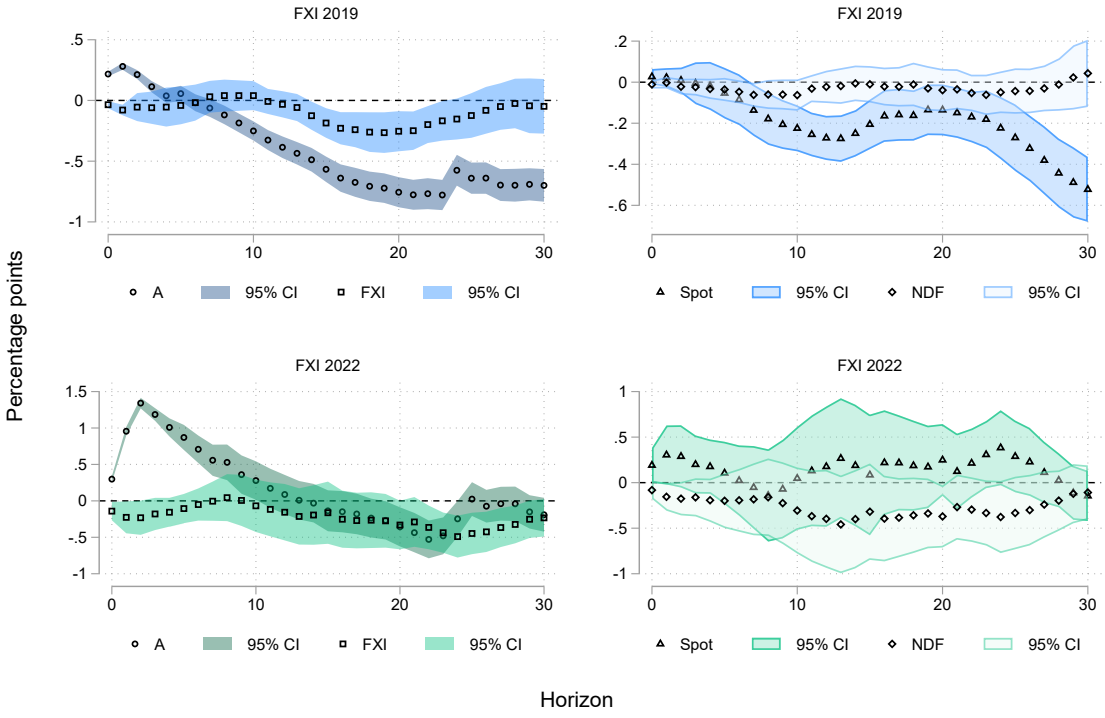


FIGURE A5. CIRF based in Equation 1 for volatility of the exchange rate, FXI 2021 and 2023

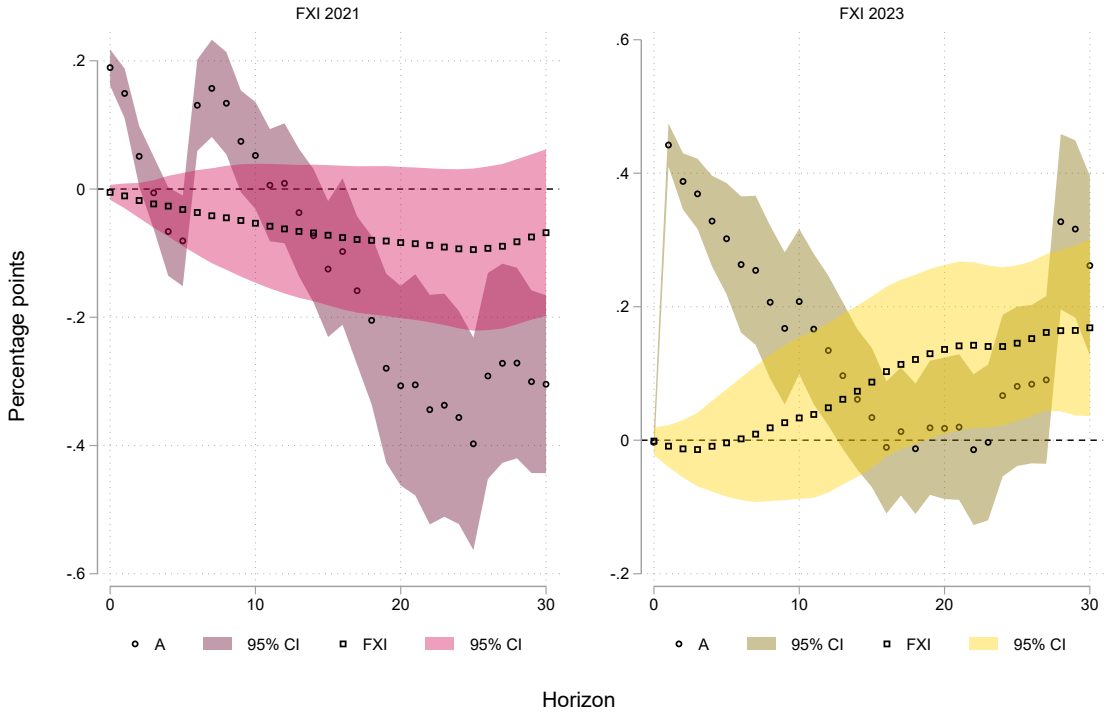
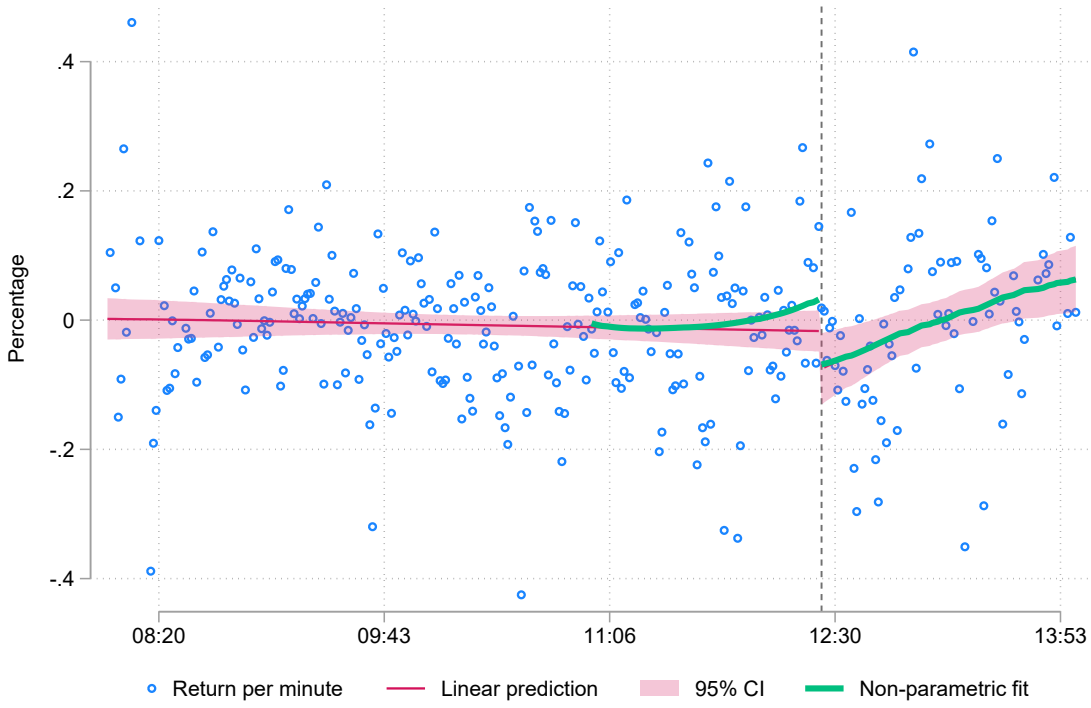
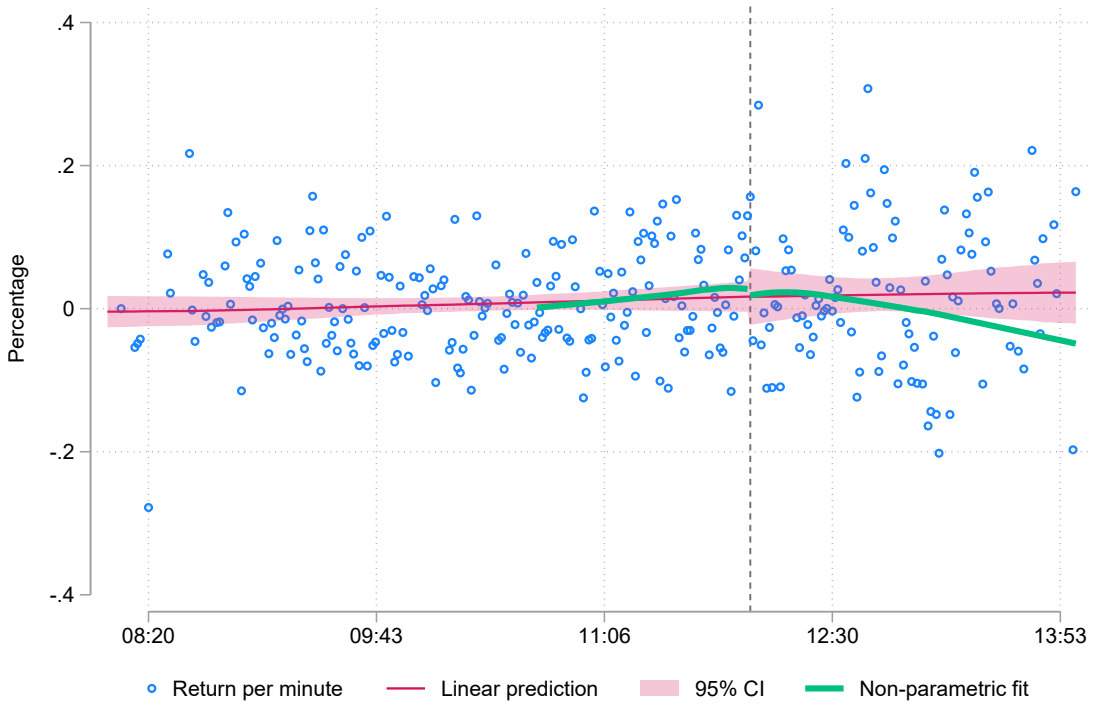


FIGURE A6. Return per minute on July 15, 2022



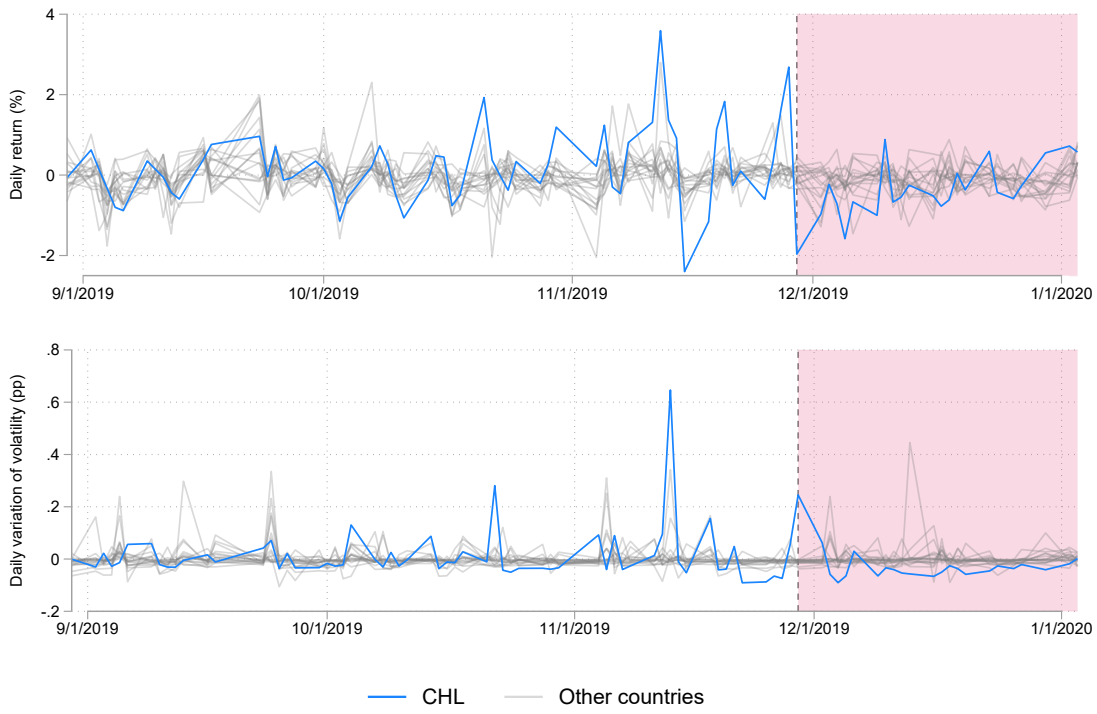
Note: the dashed vertical lines represent the loading of the announcement on the web (12:25 local time).

FIGURE A7. Return per minute on July 22, 2022



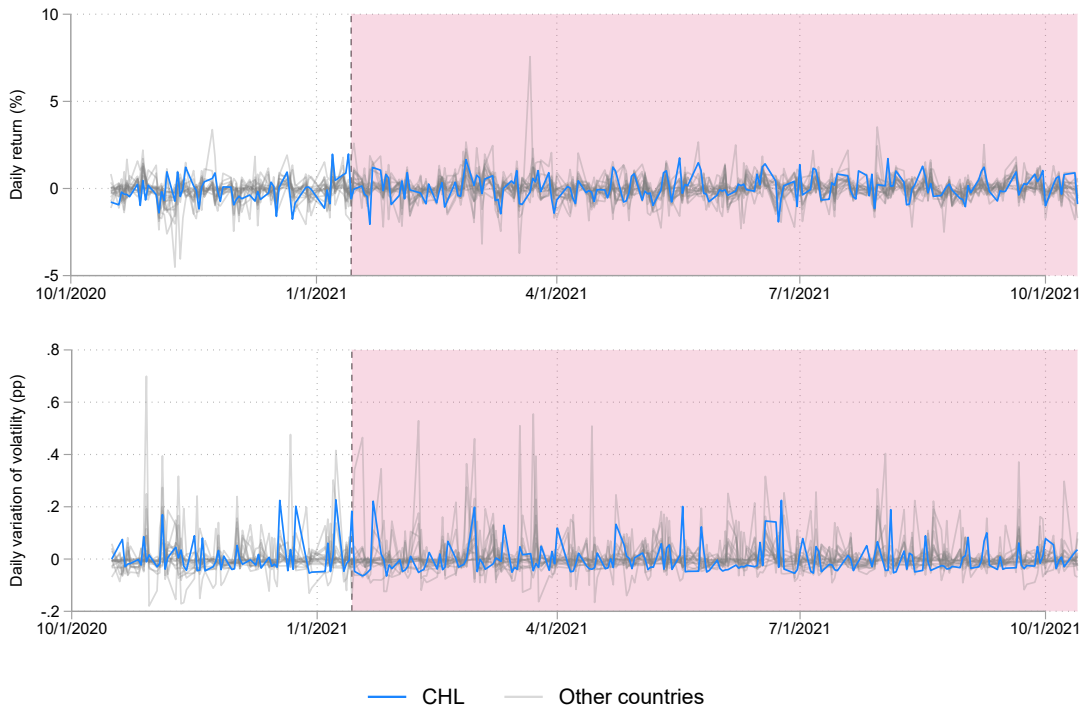
Note: the dashed vertical lines represent the loading of the announcement on the web (12:00 local time).

FIGURE A8. Evolution of exchange rates and their volatility in Chile and other countries around the 2019 FXI



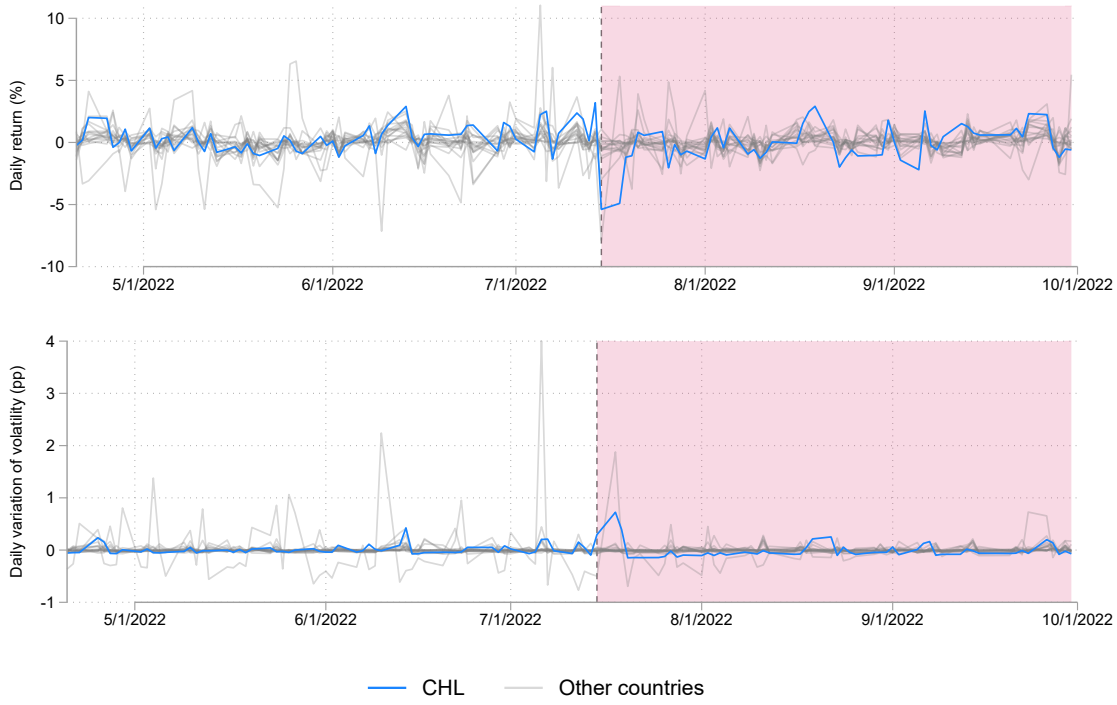
Note: dashed vertical line shows the start of the intervention. The shaded area shows the entire period of intervention (spot dollar sales).

FIGURE A9. Evolution of exchange rates and their volatility in Chile and other countries around the 2021 FXI



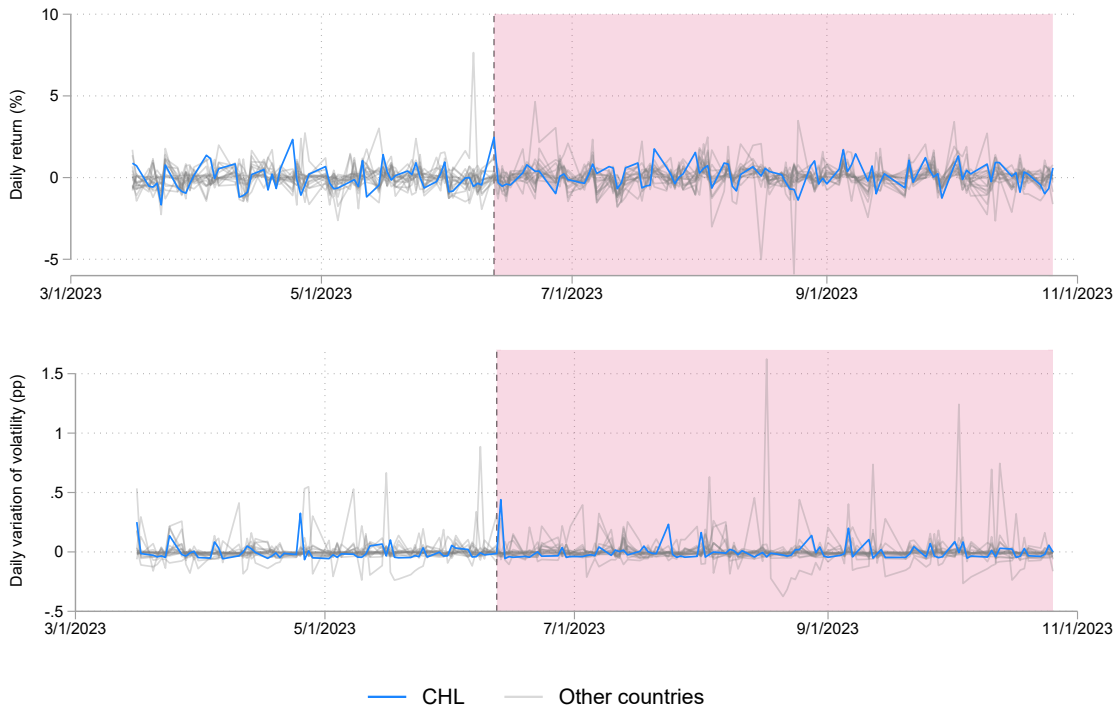
Note: dashed vertical line shows the start of the intervention. The shaded area shows the entire period of intervention (spot dollar purchases).

FIGURE A10. Evolution of exchange rates and their volatility in Chile and other countries around the 2022 FXI



Note: dashed vertical line shows the start of the intervention. The shaded area shows the entire period of intervention (spot dollar sales).

FIGURE A11. Evolution of exchange rates and their volatility in Chile and other countries around the 2023 FXI



Note: dashed vertical line shows the start of the intervention. The shaded area shows the entire period of intervention (spot dollar purchases).

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