MONETARY AND CAPITAL MARKETS

Special Series on COVID-19

The Special Series notes are produced by IMF experts to help members address the economic effects of COVID-19. The views expressed in these notes are those of the author(s) and do not necessarily represent the views of the IMF, its Executive Board, or IMF management.

February 18, 2021

Central Bank Support for Spot and Derivative Foreign Exchange Markets[1]

This note provides guidance for central bank support for spot and derivative foreign exchange (FX) markets. Interventions have increased in the context of the COVID-19 pandemic. Under these circumstances, foreign exchange interventions (FXI) may be necessary to ensure that markets are not impaired such that it becomes difficult for FX market users to manage and hedge FX risks and meet FX needs. Market impairment could lead to an exchange rate volatility that undermines the price and financial stability objectives. Compared with interventions in domestic financial markets, central bank support in FX markets is limited and should thus be designed to reach its objectives while minimizing the loss of official FX reserves. The note does not intend to revise existing IMF guidance and policy frameworks on FXI. In this context, it is important to reiterate that IMF policy continues to discourage the use of FXI to sustain misaligned exchange rates or substitute for warranted macroeconomic adjustment.

INTRODUCTION

The rationale to support FX markets is grounded in central bank mandates. Most economies present some degree of exposures to exchange rate risks which depends on their structural characteristics. Exchange rate volatility due to market impairment can threaten financial stability via the large valuation swing it could generate on unhedged FX exposures. FX interventions could, therefore, contribute to the central bank's typical mandates of price and financial stability by mitigating excessive volatility while still allowing the exchange rate to adjust to new equilibria. Consistent with IMF policy, rationales *should not* include sustaining misaligned exchange rates or substituting for warranted macroeconomic adjustment. Support to FX markets, in this context, complements monetary policy but does not directly aim at implementing a monetary policy stance. It is also separate from arrangements in which central banks handle most FX transactions in lieu of the market at predictable rates (fixed and stabilized arrangements).

[1] For more information, country authorities may contact Jihad Alwazir (jalwazir@IMF.org), Division Chief of the Central Bank Operations Division of the Monetary and Capital Markets Department. The note was prepared by Romain Lafarguette (RLafarguette@imf.org), Istvan Mak (IMak@imf.org), Asad Qureshi (AQureshi@imf.org), and Romain Veyrune (RVeyrune@imf.org). Karen Lee (KLee@imf.org) provided research assistance.

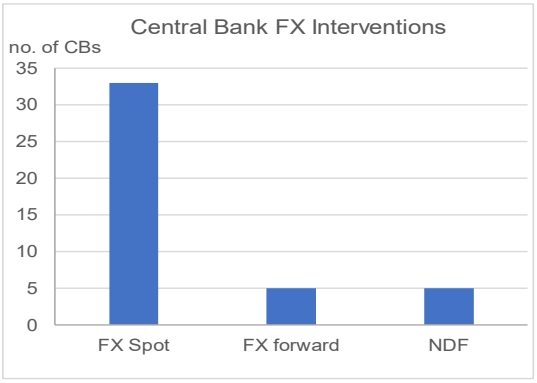
Central banks' risk management is a key element of FXI programs. Supporting FX markets entails a transfer of exchange rate risk from the private sector to the public sector. FXI in spot and derivative markets may lead to either the depletion of official FX reserves or a costly accumulation of them (depending on the direction of the pressure on the exchange rate), which entails risks to central banks. While a central bank may have to tolerate more risk to support FX markets during a crisis, prudence should influence the design of its support programs to ensure their sustainability. Excessive risk taken by a central bank may not be sustainable, and, therefore, may have an impact on the credibility of the intervention program.

This note focuses on central bank interventions that transfer exchange rate risk, namely spot and derivative transactions. FX markets may be broken down into three segments: (1) the spot FX market, which consists of purchases or sales of FX against local currency with a settlement date up to $t + 2$ (that is, two days after the transaction); (2) the derivatives FX market, understood as FX transactions settling at more than $t + 2$; and (3) FX funding markets (borrowing and lending FX). As the three segments are interconnected, developments in one market segment could affect the others. Funding markets, including FX swaps, are not treated in this note because, contrary to spot and forward transactions, they do not transfer exchange rate risk. Consequently, their impact on spot and derivative markets is limited and should not be considered as a tool for intervention in these markets.

The COVID-19 pandemic has affected FX markets in most jurisdictions. Emerging markets have experienced capital outflows in the past, but the scale of the outflows triggered by the COVID-19 pandemic in its incipient phases was unprecedented. The IMF estimates that more than US$100 billion in capital has fled emerging economies from February to September 2020. In addition, commodity-exporting economies have lost significant FX revenues due to declining commodity prices. Tourism revenues and remittances have also declined sharply. Some of the outflows were subsequently reversed but the episode illustrated the challenges of implementing sustainable intervention policy in an uncertain environment.

Central banks in many jurisdictions have intervened in FX markets during the COVID-19 pandemic. About 50 central banks intervened in FX markets. A few have used multiple instruments and intervened in multiple market segments (for example, spot and derivative) concurrently since March 2020. What follows is a summary of interventions.

- Based on publicly available information, at least 33 central banks intervened in the spot FX market to counter disorderly market conditions. Most were emerging market economies (EMEs) central banks with inflation-targeting monetary policy frameworks as well as a few advanced economies.
- Compared with other crisis episodes, interventions in derivative markets were relatively more frequent: At least 10 central banks, mostly in Latin America and Asia, intervened in forward and non-deliverable forward (NDF) markets[2].



This note reviews three general questions raised in the IMF note on "Central Bank Support to Financial Markets in the Coronavirus Pandemic" (IMF 2020b) and applies them to FX markets: (1) How does one determine whether an FX market is important for financial stability and monetary policy transmission in a given

[2] NDFs are contracts in which counterparties settle the difference between the contracted rate and the prevailing spot rate at a given date and for an agreed notional amount in local currency.

jurisdiction? (2) Under what circumstances should central banks intervene? (3) How does one design FXI in relevant FX market?

MARKET IMPORTANCE

The volume of spot FX transactions has grown over the last 15 years. According to the 2019 Bank for International Settlement Triennial Central Bank Survey (BIS 2019), the global volume of spot trades in April 2019 reached US$2 trillion per day, representing 30 percent of total FX turnover (against 49 percent for swaps and 15 percent for forwards), having grown more than three-fold since 2004. In less financially developed jurisdictions, where the FX spot market is often one of the few financial markets with some depth, FX spot markets experienced a five-fold growth. FX markets have grown with international trade and capital account liberalization, as well as the development of financial market infrastructure.

Exposure to exchange rate risk in the economy determines the importance of FX markets. The concept of exposure is extended to any loses that economic agents could incur due to a change in the exchange rate either directly due to currency mismatches or indirectly via the pass-through to domestic prices. The exposures could be to more than one bilateral exchange rate, making it somewhat more complicated to manage exchange rate risk. Therefore, an analysis of underlying exposure to exchange rate risk is important and structural features such as economic size and openness could determine the importance of the spot FX market.

A deep FX spot market is necessary for other financial markets. A market is usually considered deep and resilient if it can handle large transactions without disproportionate price reaction and while smoothly adjusting to information flows, that is, to new equilibria (Sarr and Lybek 2002). A well-functioning spot market reduces the cost for foreign investors to move in and out of local securities markets, contributing to the liquidity of local fixed-income markets (for example, government securities) and reducing funding costs.

Derivatives play a role in exchange rate risk management. Derivative instruments enable participants to secure a hedge against exchange rate risk between the trade date and the contract settlement date. To engage the derivatives market, central banks must work with counterparties (typically banks) that intermediate with end-users. Typical derivatives include FX forwards, NDFs, and FX options.[3] A functioning derivative market could bring several benefits to monetary policy and financial stability by augmenting firms' resiliency against exchange rate developments. The importance of derivative markets could be measured relative to (1) domestic banks' balance sheets, (2) net open FX positions of various sectors of the economy, and (3) spot market turnover.

Derivatives are related to the spot market. In the absence of a derivative market, agents with exchange rate exposure must pre-finance FX/domestic currency obligations with a purchase/sale in the spot market to avoid exchange rate risk. It follows that any impairment of an otherwise functioning derivative market will transfer the demand for hedging to the spot market, possibly destabilizing it. The derivative market requires a functioning spot market and money market—the underlying markets to price derivative instruments. There would be little-to-no demand for hedges if there is no exchange rate risks, that is, when authorities provide the hedge by (credibly) fixing the exchange rate, or if there is excessive volatility in the spot market, that is, hedging costs are too high. Finally, intermediaries would have difficulty supplying the hedge if capital controls limit the access to the spot market.

The choice of instruments should be consistent with the market that central banks are trying to support. The central bank should intervene in markets that are liquid in normal times and should understand the nature of

[3] Contracts that give the right but not the obligation to exchange money denominated in one currency into another currency at a pre-agreed exchange rate on a specified date.

impairment or stress it intends to address. In normal circumstances, central banks would only intervene in the derivative market to manage the demand for hedges. It would not intervene in a functioning derivative market to address disruptions in the spot market, for example, when demand for cash is the issue. However, managing the demand for hedges would have positive spillovers in the spot market due to the interconnections between these markets. There are exceptions. For example, if the derivative market is large and central to price discovery, intervening in the derivative market can be the most efficient and immediate way to support spot exchange rates.

Off-shore markets play an important role in several cases. Certain currencies are traded outside of the central bank jurisdiction (offshore). The emergence of an offshore NDF market could be for different reasons pertaining to regulations, restrictions, or limited trading hours that could constrain hedging risk onshore. These markets could be sometimes large and provide price signal that influences the onshore market. In this note, we would assume that the central bank intervenes in its own jurisdiction (onshore) because intervening in a different jurisdiction entails technical difficulties. Experiences with offshore interventions have usually not been successful and with limited effects.

INTERVENTION TRIGGERS

Several central banks mention deviation from equilibrium as a trigger for FXI in their communication with the public. One challenge is that equilibrium exchange rates are not observable, and empirical estimates in real-time are often not feasible due to the lack of high-frequency data about structural factors. Therefore, equilibrium exchange rates are not practical for defining a trigger.

Exchange rate volatility (intra-day or day-to-day) is the most commonly used indicator of market impairment. Exceptional volatility often reflects low liquidity, uncertainty regarding the equilibrium price, and impaired price discovery. In addition, exchange rate fluctuations beyond a certain level could result in sudden shifts in expectations, closing of large positions, and herding behavior among market participants, leading to persistent volatility and a durable exchange rate overshoot. Among other indicators, high volatility is considered as reflecting disorderly market conditions (DMC), which are mentioned in the Integrated Surveillance Decision (IMF 2012) as a reason for FXI.[4]

There are other indicators of market functioning. Besides exchange volatility, the DMC indicators also include bid-ask spread and implied volatility. Bid-ask spreads, both for spot and forward markets, reflect transaction costs and counterparty willingness to trade as well as market microstructure factors, such as price discovery, inventories imbalances, agents' beliefs, etc. Implied volatility reflects the expected variability of the spot exchange derived from derivatives and, thus, incorporates a forward-looking component. In addition, liquidity metrics can be derived from quantitative indicators such as transaction volumes order books and settlement data. Finally, besides quantitative indicators, market intelligence and analysis of news also play an important role in deciding whether to intervene, depending on the assessed resilience of the market.

In the context of the Integrated Policy Framework (IPF), deviations from the uncovered interest rate parity (UIP) are considered as key rationale for FXI in the spot market (Basu and others 2020, IMF 2020). In that framework, market illiquidity or dysfunction is measured by the deviation from the uncovered interest rate parity (the UIP risk premium), which arises from imperfect arbitrage by financial intermediaries in the FX market.

[4] "A member should intervene in the exchange market if necessary to counter DMC, which may be characterized inter alia by disruptive short-term movements in the exchange rate of its currency."

FXIs are considered as “optimal” when they address FX market dysfunctions which originate from impaired arbitrage, and not from a structural adjustment of the real exchange rate. FXIs are expected to reduce the UIP risk premium, thereby improving economic welfare through a realignment of the real exchange with its equilibrium value. Therefore, the IPF presents FXI as a useful complement of monetary policy, which could also have positive implications for financial stability.

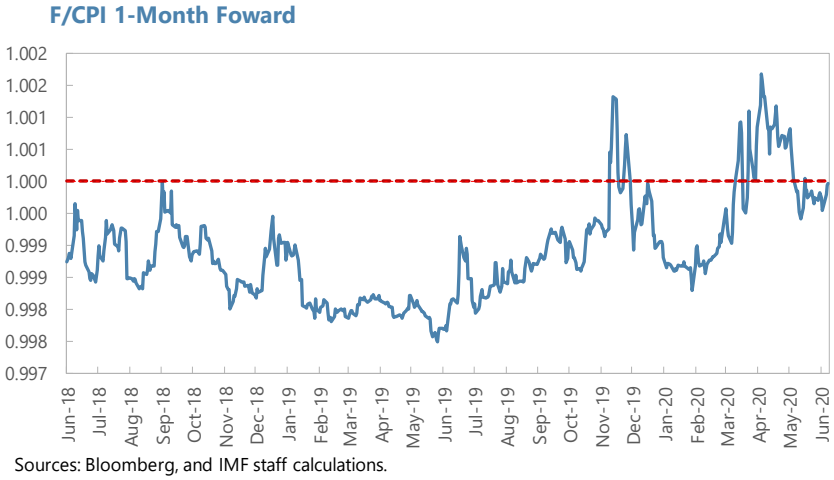
Intervention triggers should have several properties. They should (1) be flexible enough to let the exchange rate adjust to a new equilibrium while mitigating off-equilibrium deviations (consistently with the IPF) and avoiding equilibrium over-shooting, (2) depend on market conditions (an unconditional “one-size-fits-all” threshold would always be too tight or too loose as market conditions change), (3) depend on the exposure of the economy to the exchange risk and its resilience to this risk, (4) capture nonlinearities (that is, market resilience to shocks) and asymmetries between appreciation and depreciation, (5) ensure that the interventions are effective under the central bank FXI budget constraint, and (6) be operationalizable.

For forward markets and NDFs, the cost of hedging, as reflected in the Covered Interest Parity (CIP) premium, is the key variable to monitor. Post global financial crisis, balance sheet constraints of financial intermediaries, which can be both self-imposed or regulatory, have reduced incentives to arbitrage interest rate differentials (Borio and others 2016; Eguren, Ossandon Busch, and Reinhardt 2019), leading to deviations ***(α)*** between the forward rate (*F*) and Covered interest Parity (*CIP*)—the CIP risk premium. *CIP* is computed based on the spot exchange rate (*S*) and the differential between the local interest rate r^l and foreign interest rate r^f and represents the “friction-free” reference. Following Du, Tepper, and Verdelhan (2018), α reflects the demand for safe assets (US$), which is expected to increase in crisis, and the constraints on the supply; that is, the balance sheet constraints. Therefore, impairment may occur if α deviates from the level observed in non-stressed circumstances.

$$F_t = CIP_t * (1 + \alpha_t) = \frac{S * (1 + r_t^l)}{(1 + r_t^f)} * (1 + \alpha_t)$$

The computation of the theoretical forward could be challenging. The calculation should include the rates that banks effectively use to finance a forward purchase or sale. In smaller markets, indicators of the relevant rates are not always timely available.

In the example (text chart), α is used to identify periods of market stress. In normal times, α hovers around –0.2 percent for one month forward (*F*=0.998**CIP*). The local currency experienced two periods of strong depreciation pressures due to (1) an idiosyncratic shock in November 2019 and (2) the COVID-19 pandemic in March 2020. In both situations, the actual forward rate increased more than the theoretical value, pointing at an increase in the cost of hedging. The central bank of this country introduced a program of NDF sales in response to those market developments (although there is no evidence that they used α as an indicator).



Sources: Bloomberg, and IMF staff calculations.

Other factors could influence the CIP risk premium. Cerutti, Obstfeld, and Zhou (2020), highlighted other determinants of CIP deviations that are not related to crisis periods, such as international term premium differentials, US monetary policy, and others. In addition, macroprudential policies that limit the extent of unhedged FX debt in the banking sector, if in place and if they are not countercyclical, create a regulatory demand for hedge that can put pressure on the CIP risk premium in certain circumstances. Independently of its origin, an increase in the cost of hedging could have destabilizing effect on derivative and spot markets that could warrant intervention in the derivative market.

PROGRAM DESIGN

Communication. Each central bank should clearly communicate the objectives of its intervention policy to market participants and the public. While communicating, the central bank should consider that it would have to intervene to reach the announced objective and account for reaching the objective or not after the intervention. Typical objectives are variants of preserving market functioning (for example, smoothing excessive exchange rate volatility and addressing disorderly market conditions) or correcting exchange rate misalignment. Often the objective remains vague, which carries the risk of misinterpretation and may damage central bank credibility. For example, FXI may undermine confidence in the central bank's commitment to its price stability objective if it is perceived as driven by concerns about external competitiveness (Hofman and others 2020). The communication should also specify whether intervention in the derivative market aims to control hedging cost or influence the spot market.

Governance. Central banks should document the intervention process, identifying decision makers (ideally more than one person) and the basis for their action. Policy decisions should be based on objective criteria and the risks that policymakers are comfortable taking to support FX markets. In any case, FXI should not sustain misaligned exchange rates or substitute for warranted macroeconomic adjustment as per IMF policy. While it may not be possible to incorporate all relevant information in a rule that would be applied mechanically, whether to intervene would usefully include a rule to rationalize the decision process, the results of which would be reviewed by the policymakers who would use their judgment to process any additional relevant information. Finally, intervention decisions should be aligned with the monetary policy stance and expected fiscal actions.

Parameters. Intervention programs have three key parameters: the triggers (see previous section); the daily maximum intervention amount; and the budget, which determines the exchange rate risk transfers that the central banks can contemplate for a given policy objective.

- *The daily intervention maximums* should be large enough relative to the market turnover to have an impact on the exchange rate and convince market participants that intervention could have an impact on the exchange rate if the intervention parameters are made publicly available.
- *The budget*, which is necessary because of the limited FX resources of central banks, factors in (1) reserve adequacy at a certain horizon (for example, 12 months); (2) the odds of an intervention based on the adopted triggers; and (3) the maximum daily intervention. Therefore, the triggers may need to be adjusted to ensure that likely interventions remain in the intervention envelop defined by (1) and (2). Frequent updates on the budget are advisable. Forward purchases and sales should be incorporated in the spot budget based on the settlement dates.

The special case for derivatives which settle in local currency. Central banks that use NDFs that settle in local currency do not directly use FX reserves. However, NDF intervention would have an impact on domestic liquidity, the magnitude of which depends on the type of contract (notional or difference settlement, daily or monthly adjustment). This impact could be large and would have to be sterilized at a cost for the central bank. Assuming that the central bank sterilizes the liquidity injection via FX sales, or if the additional liquidity creation

might feed into demand for FX, the NDF book should be capped. For example, the cap could be set on the contract amount equivalent to the reserves in excess of the minimum adequate level at the 12-month horizon, factoring in drains from spot and outright forward intervention programs. In addition, this type of instrument should be seen as complementary to other settling in FX as the intervention success may depend *in fine* on showing both willingness and the ability to use the reserves.

Modalities for spot intervention. Intervention in spot could be allotted via bilateral or multilateral transactions. In bilateral transactions, the central bank trades either at the rate quoted by market participants or, more rarely, at its own quoted rate. In multilateral transactions, the central bank calls on market participants at a given time to show interest, for example, at an auction. Independently of whether they engage in bilateral or multilateral transactions, the central bank should transact at the best available rates in the market. This would guarantee an optimal allocation (those needing FX the most would reflect their preference by bidding higher), preserve the central bank fiduciary role by selling resources at the best price, and avoid suspicion of improprieties in the FX allotment.

Modalities for forward intervention. Intervention in derivative markets could be allotted via bilateral or multilateral transactions. The allotment objective can take two forms: (1) rolling over a defined amount of contracts (set at a share of normal trading volume and consistent with the budget limits) to guarantee a minimum depth to the market or (2) selling or buying contracts when the cost of hedging (α) exceeds a threshold that leads to a transfer of the demand to the spot market. In the latter case, the threshold should be high enough vis-à-vis the CIP to self-liquidate the program as market conditions improve. The term of the derivative used for intervention usually corresponds to the segment of the market with the most depth, which is often the shortest one (for example, one month).

Transparency. Central banks should report each month on the aggregate volume of interventions and whether specific instruments were bought or sold. A predefined lag of not more than a month should be followed (consistent with the IMF Special Data Dissemination Standard prescription on official release of reports on international reserves). More transparency regarding intervention parameters, including triggers and daily maximum amounts, could contribute to an efficient intervention strategy if market participants are convinced that a central bank will likely achieve its goals (Krugman 1991). However, many central banks do not publish their intervention parameters, suggesting that they may be concerned about market participants “gaming" them and that they would not have enough resources and flexibility to respond. Market sensitivity aspect may warrant to keep a balance in context of tactics and operations. However, policy objectives and operational framework of FXI should be clearly communicated and central bank should be able to explain outcome of its policy actions ex post. In terms of parameters of derivative intervention, some central banks announce the number of contracts, while others are transparent regarding minimum reserve prices. Finally, the rule to access central bank FXI and the allotment criteria should be clearly established and transparent.

Accountability. Internally, the service in charge of intervening should analyze whether the intervention met its objectives and whether it did so efficiently (with the minimum amount of resources necessary). The results should be disclosed to the public to ensure that expectations are aligned with central bank objectives. However, it could be challenging to demonstrate the efficiency of a volatility-based intervention in the absence of a counterfactual. One approach is to compare volatility before and after the intervention. Another one would be to analyze the profitability of intervention under the assumption that interventions to support FX market should be profitable in expectation (Friedman 1953, Sandri 2020). In any case, counterparties selection should be documented, for example, the going price in the market at the time of the intervention in the case of bilateral transactions or the bid array in the case of auctions, should be stored for internal and external audits.

FX options could be used to implement intervention rules. Options give to the counterparties of the central bank the right (but not the obligation) to buy or sell FX to the central bank if the exchange rate reaches a certain level. In practice, the strike price is often set as a certain volatility; for example, the right to buy FX if the rate is more depreciated by a certain percentage compared with the previous day or an average of several past days exchange rate. Central banks cap the amount that could be requested by the owners of the options, especially if the options give them the right to buy FX. An important feature of the option is that counterparties pay a premium for the right to access central banks' FXI. Therefore, FXI are no more "free," which should encourage prudent exchange rate risk management and reduce moral hazard. Central banks often auction a certain amount of options to determine the premiums because options are not always straightforward to price.

REFERENCES

Adrian, T., N. Boyarchenko, and D. Giannone. 2019. “Vulnerable Growth.” *American Economic Review* 109 (4): 1263–89.

Bank for International Settlements (BIS). 2019. "Triennial Central Bank Survey of Foreign Exchange and Over-the-counter (OTC) Derivatives Markets in 2019." Basel.

Basu, Suman Sambha, Emine Boz, Gita Gopinath, Francisco Roch, and Filiz Unsal. 2020. "A Conceptual Model for the Integrated Policy Framework." IMF Working Paper No. 20/212, International Monetary Fund, Washington, DC.

Borio, C., R. McCauley, P. McGuire, and V. Sushko. 2016. "Bye-Bye Covered Interest Parity." *CEPR Policy Portal,* https://voxeu.org/article/bye-bye-covered-interest-parity.

Cerutti, E., M. Obstfeld, and H. Zhou. 2020. Covered Interest Parity Deviations: "Macrofinancial Determinants." NBER Working Paper 26129, National Bureau of Economic Research, Cambridge, MA.

Chinn, M. D., and H. Ito. 2008. "A New Measure of Financial Openness." *Journal of Comparative Policy Analysis: Research and Practices.* 10 (3).

Diebold, F. X., T. A. Gunther, and A. S. Tay. 1998. “Evaluating Density Forecasts with Applications to Financial Risk Management.” *International Economic Review* 39 (4): 863–83.

Du, W., A. Tepper, and A. Verdelhan. 2018. "Deviations from Covered Interest Rate Parity." *Journal of Finance* 73 (3): 915–57.

Eguren, Martin F., M. Ossandon Busch, and D. Reinhardt. 2019. "Global Banks and Synthetic Funding: The Benefits of Foreign Relatives." *CEPR Policy Portal,* https://voxeu.org/article/global-banks-and-synthetic-funding.

Engle, R. 2001. “GARCH 101: The Use of ARCH/GARCH Models in Applied Econometrics.” *Journal of Economic Perspectives* 15 (4): 157–68.

Friedman, M. 1953. "The Case for Flexible Exchange Rate." In *Essay in Positive Economics*. 157–203. Chicago: University of Chicago Press.

Hofman, D., M. Chamon, P. Deb, T. Harjes, U. Rawat, and I. Yamamoto. 2020. Intervention Under Inflation Targeting—When Could It Make Sense? IMF Working Paper No. 20/9, International Monetary Fund, Washington, DC.

International Monetary Fund (IMF). 2012. "Decision on Bilateral and Multilateral Surveillance." Selected Decisions and Selected Documents of the IMF, Fortieth Issue, Washington, DC.

International Monetary Fund (IMF). 2019. "IMF Standards for Data Dissemination." Accessed June 11, 2020. Available at https://www.imf.org/~/media/Files/Factsheets/English/Datadissemination.ashx.

International Monetary Fund (IMF). 2020a. "COVID-19 Central Bank Interventions Database—Tableau Workbook." Washington, DC.

International Monetary Fund (IMF). 2020b. "Central Bank Support to Financial Markets in the Coronavirus Pandemic." Special Series on COVID-19, Washington, DC.

International Monetary Fund (IMF). 2020c. "Toward an Integrated Policy Framework." IMF Policy Paper, Washington, DC.

Jorion, P. 2006. *Value at Risk: The New Benchmark for Managing Financial Risk*, 3rd edition. New York: McGraw-Hill Education.

Krugman, P. R. 1991. “Target Zones and Exchange Rate Dynamics.” *The Quarterly Journal of Economics*, 106 (3): 669–82.

McMillan, D. G., and A. E. H. Speight. 2012. “Daily FX Volatility Forecasts: Can the GARCH(1,1) Model be Beaten Using High-Frequency Data?” *Journal of Forecasting* 31 (4): 330–43.

Rossi, B., and T. Sekhposyan. 2019. “Alternative Tests for Correct Specification of Conditional Predictive Densities.” *Journal of Econometrics* 208 (2): 638–57.

Sandri, D. 2020, "FX Intervention to Stabilize or Manipulate the Exchange Rate? Inference from Profitability." IMF Working Paper WP/20/90, International Monetary Fund, Washington, DC.

Sarno, L. 2003. *The Economics of Exchange Rates.* Cambridge, UK: Cambridge University Press.

Sarr, A., and T, Lybek. 2002. "Measuring Liquidity in Financial Market." IMF Working Paper 02/232, International Monetary Fund, Washington, DC.

Zumbach, G. O. 2007. "The Riskmetrics 2006 Methodology." SSRN Scholarly Paper. Available at SSRN: https://ssrn.com/abstract=1420185.