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# Making renewable energy competitive in India: Reducing financing costs via a government-sponsored hedging facility<sup>☆</sup>



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## HIGHLIGHTS

- We analyze a government-sponsored foreign exchange facility in India.
- We use geometric Brownian motion to represent the INR–USD exchange rate.
- This facility can reduce the currency hedging costs by 50%.
- This facility can reduce the levelized cost of renewable energy by 9%.
- The capital buffer to reach India's sovereign rating is 30% of the original loan.

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## ABSTRACT

In India, a significant barrier to market-competitiveness of renewable energy is a shortage of attractive debt. Domestic debt has high cost, short tenors, and variable interest rates, adding 30% to the cost of renewable energy compared to renewable energy projects elsewhere. Foreign debt is as expensive as domestic debt because it requires costly market-based currency hedging solutions. We investigate a government-sponsored foreign exchange facility as an alternative to reducing hedging costs. Using the geometric Brownian motion (GBM)<sup>2</sup> as a representative stochastic model of the INR–USD foreign exchange rate, we find that the expected cost of providing a currency hedge via this facility is 3.5 percentage points, 50% lower than market. This leads to an up to 9% reduction in the per unit cost of renewable energy. However, this requires the government to manage the risks related to unexpected currency movements appropriately. One option to manage these risks is via a capital buffer; for the facility to obtain India's sovereign rating, the capital buffer would need to be almost 30% of the underlying loan. Our findings have significant policy implications given that the Indian government can use this facility to make renewable energy more competitive and, therefore, hasten its deployment.

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## 1. Introduction

### 1.1. Motivation

India's renewable energy targets of 175 GW by 2022 are ambitious. These primarily rely on 100 GW of solar energy and 60 GW of wind energy, a 7-fold increase compared to currently installed

capacities of approximately 3 GW and 22 GW, respectively. However, the Indian government's budget is limited,<sup>3</sup> and cost-effective policy solutions are going to be crucial for achieving those targets.

Achieving these targets cost-effectively faces two major barriers related to availability and terms of debt (Shrimali et al., 2013). The availability of private capital for renewable energy investment during the period 2012–2017 is estimated to be 27% lower than required (RBI, 2012). Furthermore, in regards to terms of debt, high costs (more than 12%), short tenors (less than 10 years), and variable rates (as opposed to fixed), end up increasing the cost of renewable energy in India by 24–32% compared to renewable energy projects elsewhere (Shrimali et al., 2013).

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<sup>2</sup> Acronyms: contract for differences (CFD), foreign exchange (FX), FX hedging facility (FXHF), geometric Brownian motion (GBM), levelized cost of electricity (LCOE), power purchase agreement (PPA).

<sup>3</sup> The budget allocated to India's Ministry of New and Renewable Energy (MNRE) was reduced from USD 246 million in FY2013–14 to USD 72.3 million in FY2014–15 (MNRE, 2014).

Thus, to achieve India's renewable energy targets cost-effectively, more debt is required at attractive terms – i.e., with reduced costs and extended tenors. Foreign loans (e.g., in USD) are attractive for Indian policymakers, given that cheaper (at 5–7%), longer-term (15 years or more), fixed-rate foreign loans have the potential to reduce the cost of government support by reducing the cost of renewable energy (Shrimali et al., 2013; CPI, 2014a). The FXHF can reduce the cost of debt and given that low cost, long term debt reduces the cost of renewable energy, the FXHF has the potential to reduce the cost of renewable energy.<sup>4</sup>

However, given that renewable projects earn revenues in local currency (in INR), financing a renewable energy by a foreign loan (in USD), the mismatch in the currency of debt obligations and currency of revenue exposes the project to the risk of devaluation in the latter over time,<sup>5</sup> resulting in reduced investments in the country due to the higher perception of risk,<sup>6</sup> and necessitating the use of a currency hedge (or foreign exchange swap) to protect against these devaluations.

But, market-based currency hedging solutions are expensive in India. High costs of hedging increase the final cost of debt, and almost entirely eliminate the benefit of potentially cheaper foreign loans.<sup>7</sup> For example, the typical cost of currency hedging in India is around 7% per year (or higher, depending on the credit rating of the borrower),<sup>8</sup> making completely hedged foreign loans as expensive as domestic loans – i.e., at 12–13% (Shrimali et al., 2013).

Thus, it is clear that reducing the cost of foreign loans via reducing the currency hedging cost can reduce the final cost of debt and, therefore, the cost of capital. This would reduce the delivered cost of renewable energy,<sup>9</sup> and reduce the government cost of support (CPI, 2014a), by making renewable energy more competitive with electricity from fossil fuels (Shrimali et al., 2013). This would also increase the attractiveness of foreign debt compared to domestic debt, mobilize foreign capital and spur investments in renewable energy. This motivates the investigation of provision of cheaper government-supported currency hedging solutions for renewable energy projects as a policy option.

The Government of India has realized that, in order to reach its ambitious renewable targets cost-effectively, cheaper currency hedging mechanisms can play a crucial role, given its role in facilitating provision of low-cost, long-tenor debt. This critically hinges on the

<sup>4</sup> The lowest solar tariff bid in India by SunEdison (at INR 4.63/unit) is speculated to have been possible due to low cost debt (<http://www.thehindubusinessline.com/economy/solar-tariffs-in-india-hit-alltime-low-of-rs-463/article7841242.ece>). This is at least 10% lower than bids by developers using debt at market rates. These bids typically reflect the levelized cost of electricity.

<sup>5</sup> In theory, INR has a market-determined exchange rate. However, the Reserve Bank of India (RBI) can intervene actively in cases of excessive volatility (HSBC, 2012).

<sup>6</sup> Currency risk is a major barrier to foreign investments in India and other developing countries. Currency crises, defined as a quick decline (more than 20% in one year) of a local currency vis-a-vis USD, have triggered regional economic crises such as in Latin American in 1982. Laeven and Valencia (2013) report 217 currency crises over the period 1970–2011 worldwide. While all projects with foreign investments face currency risk, infrastructure projects are exposed to greater risk because of their longer terms (20–30 years). Further, as Infrastructure assets are difficult to re-deploy, exit is more difficult for investors. Currency risk is more severe for the power sector since its output is not only heavily regulated but also not tradable in international markets.

<sup>7</sup> For currency risk mitigation, foreign infrastructure investments in India have traditionally relied either on market based currency hedging mechanisms or on natural hedging. However, many firms in India are now taking currency risk exposure based on speculation, evident from the fact that more than 75% of external commercial borrowing (ECB) in India is un-hedged. Such decisions are largely driven by the high cost of hedging in the market.

<sup>8</sup> From Bloomberg Terminal, last accessed in January 2015.

<sup>9</sup> For this paper, delivered cost of renewable energy includes the per unit generation (only) cost to the consumer. In most cases, this is the same as the levelized cost, which is the per unit revenue required for a project to be viable; however, in some cases, it may include surcharges.

finding that renewable energy is still more expensive – 50% or higher – than conventional energy and requires federal policy support (Shrimali et al., 2014). More importantly, provision/facilitation of low-cost, long-tenor debt is the most cost-effective federal policy solution – by 75% or higher compared to existing federal policies<sup>10</sup> – for deploying renewable energy (Shrimali et al., 2014).

The government has demonstrated clear interest in providing cheaper currency hedging for renewable energy, using a currency hedging facility (Economic Times, 2015), using the National Clean Energy Fund which has been created by levying a tax on coal (Mint, 2015). This hedging facility would be available for foreign currency loans obtained by qualified renewable energy projects, ensuring that the advantage of such a facility is targeted towards renewable energy, a policy priority for the Indian government.

This, however, raises the question of whether governments should be actually be involved in the management of currency risk. Given that government policies can influence macroeconomic conditions, which in turn are primary drivers of currency rates (ADBI, 2006); there is an argument for governments providing a currency hedging solution in strategic situations.<sup>11</sup> Given that governments may be in the best position to bear (and respond to) currency risk, they can choose to bear this risk in certain strategic situations, such as deployment of renewable energy.<sup>12</sup> Though such a currency hedging facility is applicable to any sector in the economy, given the government's policy priorities, we have considered it exclusively for renewable energy only.

A further argument for governments, the Indian government in particular, providing cheaper currency hedging is that it helps them reduce import dependence. Bearing the currency risk for renewable energy would offset the currency risk the government takes on future imported fossil-fuel purchases in an import dependent economy like India. In the case of electricity generation in India, this is very relevant for imported coal, the marginal fossil fuel (CPI, 2015).

However, the currency hedging solutions that the government has announced so far do not fully assess the risks associated with foreign exchange (FX) rate hedging adequately. These proposals discuss the average rate the Indian currency (INR) has depreciated against the USD, and propose a facility that addresses this average depreciation. However, currency movements can also be unexpected and uncertain, depending on short-term macro-economic conditions and resulting investor sentiment.<sup>13</sup> This requires an in-depth assessment of not only the expected cost of providing such a hedging facility but also the risk implications.

## 1.2. Research questions

In this paper, using a representative stochastic model of the USD–INR exchange rate, we analytically examine a foreign

<sup>10</sup> These policies include viability gap funding (VGF), a form of capital subsidy; accelerated depreciation, a form of tax benefit; and generation based incentive, a form of generation subsidy.

<sup>11</sup> The Indian government has in the past offered currency protection. However, this protection only applied to investments in roads and—most importantly—only in an event of default. This still does not cover the much more likely situation that the project does not default but the local currency depreciates significantly (Lambert, 2014).

<sup>12</sup> The standard principle of risk allocation is based on allocating the risk to the party that may be able to best manage it. For power projects, the parties that can bear the currency risk are – the project developers, the government or the customers. Project developers often bear currency risk. Sometimes, currency risk is passed on to the consumers. However, the government may be in a better position to bear currency risk as it can influence this risk.

<sup>13</sup> Forecasting exchange rates in a deterministic manner is not easy because each of the existing exchange rate theories holds only in specific settings; none contains all the significant factors that could have an impact on currency rates (ADBI, 2006).

exchange hedging facility, which does not require an explicit sovereign guarantee,<sup>14</sup> by explicitly providing reserves (or capital buffers) that match a country's sovereign debt rating. To the best of our knowledge, such a facility has so far not been analyzed in detail before.

Specific questions that we will seek to address are:

- *How can such a facility be structured?* The structure of the facility includes the currency hedging contract between the hedging facility and the counterparty, the reserve account and the risk mitigation mechanism of the hedging facility.
- *What will be the expected cost of such a hedging facility?* The expected cost refers to the most likely cost of covering the currency risk. The hedging facility would be beneficial only if it can provide currency hedging at a cheaper expected cost than the market.
- *What will be the impact of the hedging facility on the delivered cost of electricity?* The key benefit of the hedging facility to the government lies in its impact on the delivered cost of renewable energy, which is directly proportional to the government cost of support for renewable energy.
- *What will be the risk implications?* The risk of uncertain and volatile currency movements will be quantified and addressed appropriately with a suitable risk absorbing mechanism, such as the capital buffer

### 1.3. Literature review

Given the novelty of our work, there are no direct analogs in prior work; in particular, in academic literature. However, in this section, we cover two types/classes of relevant literature: one that examines management of foreign exchange risk for infrastructure (and, therefore, renewable energy) projects; and another that examines application of stochastic analysis to problems in renewable energy and/or climate.<sup>15</sup>

For the management of foreign exchange risk in infrastructure projects, Matsukawa et al. (2003) provide a comprehensive review of risk management instruments, including: local currency financing, foreign exchange hedges, mechanisms that allocate foreign exchange rate risk to the government, tariff indexes, and liquidity facilities. They provide brief descriptions of each along with suitable case studies of previous implementations. The liquidity facilities come closest to our foreign exchange hedging facility. They do not provide any design guidelines, however.

On the other hand, Irwin (2007) is the de-facto reference for valuing and allocating risk (especially foreign exchange risk) for government guarantees in privately financed infrastructure projects. He provides suitable theoretical as well as simulation-based frameworks for calculating expected costs as well as capital buffers when the underlying processes are stochastic in nature. Though, he did not address the specific problem of the foreign exchange hedging facility for renewable energy in India, our work greatly benefited from his general frameworks.

The closest match to our foreign exchange risk hedging facility appears in a standby credit facility offered by the Overseas Private Investment Corporation in the AES Tietê transaction (Grey and Irwin, 2003). To finance the debt of multiple generating facilities, AES issued US \$300 million in dollar bonds. The tariff was indexed to local inflation, ensuring that the facility had to deal with only real (not nominal) currency devaluation. A US \$30 million liquidity

facility was provided to cover extreme real currency devaluations. However, this structure is fundamentally different from ours. First, it managed real foreign exchange risk as opposed to nominal exchange risk. Second, it did not use stochastic process modeling, and relied on rule of thumb calculations. Third, it was dependent on inflation-indexed tariff adjustments, which involved political risk.

Despite the practical application of these papers, which belong to the first class mentioned above, are published by the World Bank (Matsukawa et al., 2003; Irwin, 2007; Grey and Irwin, 2003), they do not appear in academic journals. On the other hand, we find many relevant academic publications belonging to the second class, as discussed below; however, none of these address the specific problem of foreign exchange risk management for renewable energy.

Tang et al. (2012) examine the formulation of a carbon revenue bond, where the carbon revenue from a renewable energy project is dependent on carbon credit prices, which are assumed to follow a stochastic distribution. They find that a carbon revenue bond, with a 10 year tenor, can finance a significant fraction of a project's initial cost, or capital expenditure. Though our problem is fundamentally different, we learned from the modeling of stochastic processes and their subsequent application.

Alafita and Pearce (2014) examine the formulation of renewable energy bond, based on securitization of cash flows emanating from the cash flows of underlying distributed solar PV projects. These cash flows are again assumed to have a stochastic distribution. They find that this securitization can result in significantly reducing the financing costs (and, therefore, delivered cost) of underlying solar projects, a finding that we find analogs of, in terms of reduced financing costs due to reduce foreign exchange hedging costs.

We next discuss the structure of the foreign exchange hedging structure in Section 2. At the end of Section 2, we provide the outline of the rest of the paper.

## 2. The foreign exchange hedging facility structure

A government-sponsored FXHF ("the FXHF") could be a cheaper mechanism for effectively supporting hedging of currency risk. Comparing to currency hedging in the market, the FXHF would provide hedging for expected currency depreciation and unexpected and extreme currency depreciation separately, and hence providing greater control over risk exposure and risk assessment. We note that we do not start with an explicit assumption that the government sponsored FXHF would be cheaper than market-based hedging; however, as we would see subsequently, by appropriately managing (and sharing) risks, it is a possibility.

Under the FXHF, the government can help provide project developers and/or off-takers (for example, public distribution companies) protection from currency risk through a standalone fund. The cash flows under the FXHF depend on whether the project's power purchase agreement (PPA) is based on local currency (INR) or hard currency (USD). Though both of these models are described below, given that differences are subtle, in the rest of the paper we focus mostly on the former mechanism – i.e., when the PPA is in the local currency.

### 2.1. An FXHF for a local currency power purchase agreement

Under a local currency power purchase agreement, the project developer borrows in foreign currency (i.e., USD); therefore, the foreign exchange risk exposure is borne by the project developer. In this case, the FXHF can enter into a swap – contract for

<sup>14</sup> In fact, the Indian government policy prohibits supporting currency hedging using sovereign guarantees (Ministry of Finance, 2010).

<sup>15</sup> We note that, despite the comparison to stochastic analysis in problems in renewable energy and/or climate, our stochastic analysis is related to uncertain foreign exchange rates.

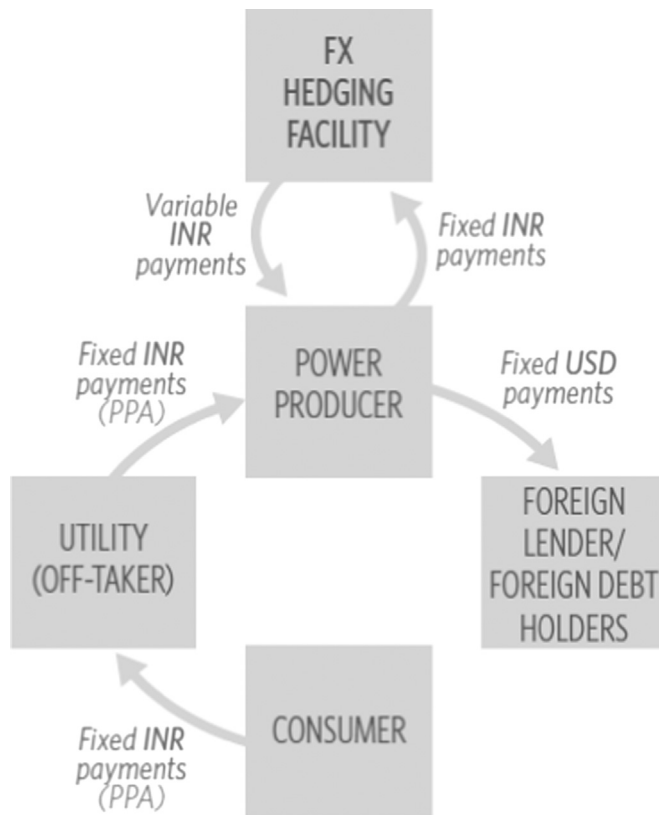


Fig. 1. Cash flows in a local currency PPA.

differences (CFD)<sup>16</sup> – with the project developer.

Under a contract for differences, the two parties would sign a contract at a fixed foreign exchange rate and exchange payments for the differences between the actual and the contracted foreign exchange rates. The following flow-chart (Fig. 1) depicts the flow of payments for an FXHF for a local currency power purchase agreement.

For example, if the fixed rate is 1 USD=63 INR, then, at fixed periods when debt payments are due (e.g., yearly or quarterly), if the foreign exchange rate is higher than 1 USD=63 INR, the FXHF would make a net payment to the project developer. This net payment is essentially equal to the difference of the variable payment (equal to the USD debt payments at the actual foreign exchange rate) from the FXHF to the developer and the fixed payment from the developer to the FXHF (equal to the USD debt payments at the contracted foreign exchange rate). Otherwise (if the foreign exchange rate is lower than 1 USD=63 INR), the project developer would make a net payment to the FXHF. Thus, it is possible to have a net payment flow in either direction – from the FXHF to the project developer or from the project developer to the FXHF. However, for a continuously depreciating currency – e.g., the INR vs. the USD – the expected net payment is always from the FXHF to the project developer.

## 2.2. An FXHF for a hard currency power purchase agreement

Under a hard currency power purchase agreement, an off-taker is exposed to the foreign exchange risk, given that its revenues (from the customers) are in INR, but the liabilities are in USD. Since it may be politically difficult to pass the full foreign exchange risk

to the customers,<sup>17</sup> a hard currency power purchase agreement could put severe strain on off-takers – in particular, distribution companies – if the foreign exchange risk is not adequately covered, especially because of the poor financial health of Indian distribution companies (Natural Group, 2013). In this case, given that the foreign exchange risk is taken by the off-taker, or the distribution company, the FXHF will enter into a contract for differences with the off-taker instead of the project developer. The following flow-chart depicts the flow of payments for a hard currency power purchase agreement (Fig. 2):

## 2.3. Design considerations for an FXHF

The design of the FXHF would remain very similar under both a local currency and hard currency power purchase agreement. Only the counterparty (i.e., the entity entering into the contract for differences with the FXHF) would be different. Under a local currency power purchase agreement, the counterparty would be the project developer; while under a hard currency power purchase agreement, the counterparty would be the off-taker.

However, designing the facility would not be an easy undertaking, given that currency movements can be not only uncertain but also volatile. The design of the FXHF, therefore, requires detailed analysis of the following:

- **Expected cost:** The expected net payments by the FXHF. This would be the net present value of the difference between the variable INR payments from the FXHF to the counterparty and the fixed INR payments from the counterparty to the FXHF. The net present value concept recognizes explicitly the opportunity cost of using sovereign funds for the FXHF and, therefore, uses the government cost of capital as the discount rate (see Section 3.2). We assume that this is passed on to the counterparty and, therefore, can be taken as the cost of using FXHF.
- **Risk exposure:** The different risks – explicit and implicit – that the FXHF may face. The explicit risk is the risk of extreme and unexpected movements in the foreign exchange rate, above the expected movement analyzed in above. The implicit risks are many, including the credit risk of the FXHF, the power off-taker risk, etc. However, for the purpose of this paper, we focus only on the explicit risk.
- **Capital buffer:** The amount required, beyond expected cost, to address unexpected and extreme movements in the foreign exchange rate. This buffer would ensure that, given a particular probability of default, the FXHF does not default (i.e., run out of money).
- **Size:** The total size of the FXHF, which is the sum of the expected cost and the capital buffer. This is the size of the FXHF required to ensure that the FXHF not only takes care of the expected cost but also provides the capital buffer for unexpected and extreme movements.

All of these require forecasting of foreign exchange rates. In Section 3, we provide the methodology (and discuss data) including: forecasting foreign exchange rates, analyzing parameters (expected cost as well as risk implications) of the FX hedging facility, and calculating the impact on the levelized cost of electricity. In Section 4, we present our results and discuss implications of our results for the cost of debt as well as the delivered cost of electricity. Finally, in Section 5, we conclude and provide policy implications.

<sup>16</sup> The FX risk exposure of the project developer can be fixed at a pre-determined level beyond which FXHF will cover the risk by paying cash to the project developer. The frequency of this payment would be similar to debt payment obligations of the project developer.

<sup>17</sup> Hard currency PPAs have not worked well in Indonesia and Argentina as, under political pressure, the governments refused to increase tariffs in response to currency depreciations under extreme stress situations. India experimented with such a tariff mechanism unsuccessfully with a combined cycle gas plant in 1997 (CPI, 2014b).

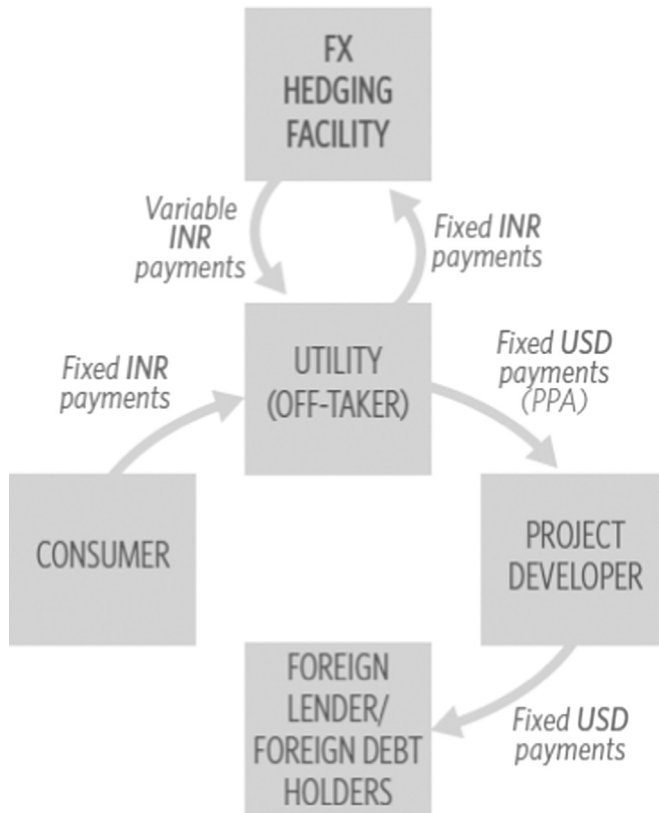


Fig. 2. Cash flows in a hard currency PPA.

We note that this work is a preliminary investigation, and the final design of the FXHF would involve further detailed analysis as noted in Section 5. We also note our implicit assumptions: first, it is possible to forecast foreign exchange rates; and second, it is possible to not only provide a hedging solution with an expected cost but also to design a robust FXHF using an appropriate capital buffer. We understand that these assumptions can be challenged; however, we believe that our analysis is a good first step.

### 3. Methodology and data

The methodology employed in this section covers three key aspects involved in the investigation of the foreign exchange hedging facility: (i) forecasting foreign exchange rates using annual foreign exchange time series data (Section 3.1);<sup>18</sup> (ii) calculating the impact of the hedging facility on the cost of renewable energy (Section 3.3), which includes a calculation of the expected hedging costs of FXHF (Section 3.2); and (iii) calculating the capital buffer required to manage unexpected and extreme currency devaluations (Section 3.4), including an assessment of the market cost of managing the capital buffer (Section 3.5).

#### 3.1. Forecasting foreign exchange rate

Several exchange rate theories exist in literature. Most of these include either structural models based on some basic independent variables or time series models. A structural model for a foreign exchange forecast is based on several economic and non-economic variables. Different exchange rate theories are used as foundations

for such structural models (ADBI, 2006).<sup>19</sup> These include partial equilibrium models, general equilibrium models, and hybrid models. Each of these theories holds in a particular context (only) and explains the impact of some macroeconomic conditions. However, no single theory comprehensively explains currency movements (ADBI, 2006). On the other hand, the commonly used time series models for FX rate forecasting include ARIMA models (Box and Jenkins, 1970), VaR models (Johansen and Juselius, 1990) and the model proposed by Meese and Singleton (1982).

Due to limitations of both the structural and time series models, stochastic models have been gaining popularity in theory as well as in practice. Mussa (1979) was the first to observe that the spot values of foreign exchange rates as well as their (logarithmic) returns follow a stochastic process. Meese and Rogoff (1983a, 1983b) compared structural and stochastic models, and concluded that former performed poorly. Cheung et al. (2005) assessed exchange rate predictions using a wider set of models, and concluded that no model consistently outperformed a stochastic process. Gozgor et al. (2010) also concluded that stochastic processes consistently outperformed time series models for currency (i.e., USD-TL) exchange rates.

A stochastic model considers cumulative (or combined) effects of multiple uncertainties (over the variables typically used in structural models) on the foreign exchange rate and these models are regularly used in the market to price foreign exchange swaps and options. Our long-term INR–USD exchange rate forecast involves the following steps: first, choosing an appropriate stochastic process; second, determining the key parameters of the stochastic model; and third, using the stochastic model to forecast the INR–USD exchange rate, using Monte-Carlo simulations (Irwin, 2007).

#### 3.1.1. The stochastic model: geometric Brownian motion

In a simple stochastic model, FX rates behave like a geometric Brownian motion (GBM). Under a GBM, the underlying foreign exchange rate is characterized by a trend (deterministic) component and a random (stochastic) component.

Representing a foreign exchange rate with a GBM is based on the assumption that the underlying logarithmic returns are normally distributed. That is, the underlying assumption is that all the uncertainties affecting the foreign exchange rates are not only independent but also none of them are dominant. This assumption may be violated in certain situations, given that many of the uncertainties that affect foreign exchange rate, including government policies, may not satisfy these conditions.

Despite potential issues, GBM provides a reasonable, and first-order, approximation to exchange rate movements, and has been extensively used for modeling purposes in academia as well as in the finance industry. For example, in the exchange rate market, vanilla (i.e., the simplest) foreign exchange option prices are generally quoted using the Black–Scholes framework, which is

<sup>19</sup> These models include the following (ADBI, 2006):

- Partial equilibrium models are single factor models. These include: (relative or absolute) power purchase parity (PPP), which focuses on only the goods market; (covered or uncovered) interest rate parity, which focuses on only the assets market; and the external equilibrium model, which focuses only on the balance of payments.
- General equilibrium models are more complex models. These include: the Mundell–Fleming model, which considers the equilibrium of the goods market, money market and balance of payments; the Balassa–Samuelson model, which considers maximization of firms' profits; the pricing to market model, which considers maximization of consumers' utilities; and the Redux model, which was developed by Obstfeld and Rogoff.
- Hybrid models, such as the Dornbusch model, are obtained by combining the monetary equilibrium model with the adjustment of prices outputs in the long-term, and can therefore be referred to as hybrids of monetary equilibrium with purchase power (or interest rate) parity.

<sup>18</sup> This is for demonstration purposes only. Quarterly data can be used to match the actual flows from the FXHF, based on loan repayment profiles.

based on a GBM. Also, the popular currency option pricing model proposed by Heston (1993) is derived from GBM. In a long term capital budgeting framework, Hooper and Pointon (1995) also applied the GBM process to model exchange rate behavior.

The following stochastic differential equation represents a GBM for a foreign exchange rate:

$$dS_t = \mu S_t dt + \sigma S_t dW_t, \tag{1}$$

where  $\mu$  is the drift rate and  $\sigma$  is the standard deviation;  $\mu S_t dt$  is the trend (deterministic) component and  $\sigma S_t dW_t$  is the stochastic (random) component. The solution of Eq. (1) gives the following process representing a foreign exchange rate:

$$FX_t = FX_0 \exp\left[\left(\mu - \frac{\sigma^2}{2}\right)t + \sigma^* W_t\right], \tag{2}$$

where  $FX_t$  is the foreign exchange rate at time  $t$ ,  $FX_0$  is the foreign exchange rate at time  $t=t_0$ , and  $W_t$  is a Weiner process. In Eq. (2),  $(\mu - \sigma^2/2)t$  represents the trend component and  $\sigma^* W_t$  represents the stochastic component of the foreign exchange rate movements.  $W_t$  can be further written as:

$$W_t = Z^* \sqrt{t}, \tag{3}$$

where  $Z$  is normally distributed random number between 0 and 1.

### 3.1.2. Extracting $\mu$ and $\sigma$ for a GBM: the maximum likelihood estimation (MLE)

To use a GBM for forecasting purposes, two key parameters of the GBM need to be estimated – the  $\mu$  and  $\sigma$ .  $\mu$  can be derived from historical values of foreign exchange rates or from inflation (or interest rate) differentials. However, deriving  $\mu$  from inflation differentials would lean towards theories of partial equilibrium model, which don't appear to hold for the INR–USD exchange rate.  $\sigma$  can be taken either as a constant or be modeled as a dynamic function of time (Heston, 1993). However, it is not uncommon to take  $\sigma$  as a constant – for example, while pricing vanilla foreign exchange options. Therefore, we assumed that a historical foreign exchange rate time series can provide reliable estimates of trend and random components in the foreign exchange rate movements.

To find  $\mu$  and  $\sigma$  that yield the best fit to a historical dataset, we used the commonly used maximum likelihood estimation (MLE) – that is, we derived the most likely parameters of a GBM that would represent this dataset (Brigo et al., 2007). The following closed form expressions for the mean and variance of the log returns samples  $x_i = \log FX_{t,i} - \log FX_{t,i-1}$ , were used as the MLE estimates:<sup>20</sup>

$$m = \sum x_i / n ; v = \sum (x_i - m)^2 / n, \tag{4}$$

where  $m = (\mu - \sigma^2/2)$ ,  $v = \sigma^2$  and “ $n$ ” is the number of samples. Given “ $m$ ” and “ $v$ ”, the required  $\mu$  and  $\sigma$  can be calculated in a straightforward manner.

For forecasting purposes, to model for the case that the foreign exchange rate on the day of INR–USD conversion may be higher than the yearly average, we focused on the “yearly maximum” foreign exchange time series. Based on 20-year<sup>21</sup> data (1995–2014), MLE provided  $m=0.0292$  and  $v=0.00543$ ; resulting in  $\mu=0.0319$  and  $\sigma=0.0737$ , or  $\mu=3.19\%$  and  $\sigma=7.37\%$ .

<sup>20</sup> These are derived as the solution for the maximum of the log-likelihood function of the underlying probability distribution.  $FX_{t,i}$  denotes the FX rate at time  $t_i$  and  $FX_{t,i-1}$  denotes the FX rate at time  $t_{i-1}$ .

<sup>21</sup> The time series data has been taken from the year 1995, given that INR has full current account convertibility since then. The source for this data is: (<http://www.oanda.com/currency/historical-rates/>).

### 3.1.3. Forecasting foreign exchange rates: Monte-Carlo simulations

We forecast the INR–USD foreign exchange rate for 10 years, given that this tenor matches the tenor of the longest available market based hedge, and this allows for a comparison with the market.

For the USD–INR foreign exchange rate forecast for years 2015–2024 ( $t=1-10$  years), we used:  $FX_0$  (foreign exchange rate at the end of the year 2014)=63,  $\mu=3.19\%$ ,  $\sigma=7.37\%$ . Using the GBM Eq. (1), we generated 10,000 foreign exchange rate samples for every time period – that is, for  $t=1-10$  years. We then created histograms – i.e., probability distributions – based on each of these 10 sets of 10,000 predictions. Fig. 3, for example, shows the histogram for the year 2024 (i.e., for  $t=10$ ). Based on associated probability levels, these histograms were then used to calculate expected costs as well as risk implications; for example, P50, P95, etc., where P95 refers to the level below which 95% of the distribution lies.

### 3.2. The expected cost of the FXHF

The expected cost of managing the FXHF under the contract for differences (see Section 2) is essentially the net present value of the net payments – the debt payment multiplied by the difference in the actual and contracted foreign exchange rates – from the FXHF. Based on the histograms (e.g., Fig. 3), for a typical renewable energy project, this can be calculated a straightforward manner, as follows (we used a 10-year fixed rate USD loan to match usual practice):

- Calculate the fixed yearly INR payments by the counterparty (i.e., the developer in a local currency PPA – see Section 2) to the FXHF based on the initial/contracted FX rate,  $FX_0$ . Denote this time series of payments by “A”.
- Forecast the USD–INR FX rate using the methods in Section 3.1. Create histograms for each year from year 1 to year 10.
- Calculate the variable yearly INR payments by the FXHF to the counterparty (see Section 2) based on the expected values (i.e., P50s) of forecasted FX rates. Denote this time series of payments by “B”.
- The difference time series (i.e.,  $C=B-A$ ) is the expected net payment from the FXHF to the counterparty. Calculate the net present value (NPV) of “C” at the government's cost of capital, denoted by “D”.
- Find an annuity on the original loan whose NPV is equivalent to “D”. The implied rate on this annuity is the expected cost of the hedging provided by the FXHF – i.e., FXHF expected cost.

### 3.3. The impact on the delivered cost of renewable energy

The expected cost of hedging using the FXHF impacts the levelized cost electricity (LCOE) of renewable energy via its influence on the final expected cost of the INR debt that the counterparty (and, therefore, the renewable project) faces. Essentially, if the project's per unit revenue is the LCOE, the project has a zero net present value (NPV) (Brealey et al., 2007). That is, the LCOE represents the average (or “levelized”) cost of generating electricity from the project. Given the intricacies of project-level cash flow modeling, it is hard to establish formulas for the LCOE; however, a representative formula that provides intuition for the LCOE for a project that lasts  $T$  years is as follows (Shrimali, 2011):

$$Lc = \frac{C - \alpha \sum_{t=1}^T \frac{D_t}{(1+r)^t} + (1-\alpha) \sum_{t=1}^T \frac{W_t}{(1+r)^t} - (1-\alpha) \frac{C_T}{(1+r)^T}}{(1-\alpha) * 8760 * \sum_{t=1}^T \frac{CF_t * X_t}{(1+r)^t}} \tag{5}$$

where  $C$  is the initial capital expenditure (or CAPEX);  $D$  is the yearly depreciation;  $W$  is the yearly operating expenditure (or

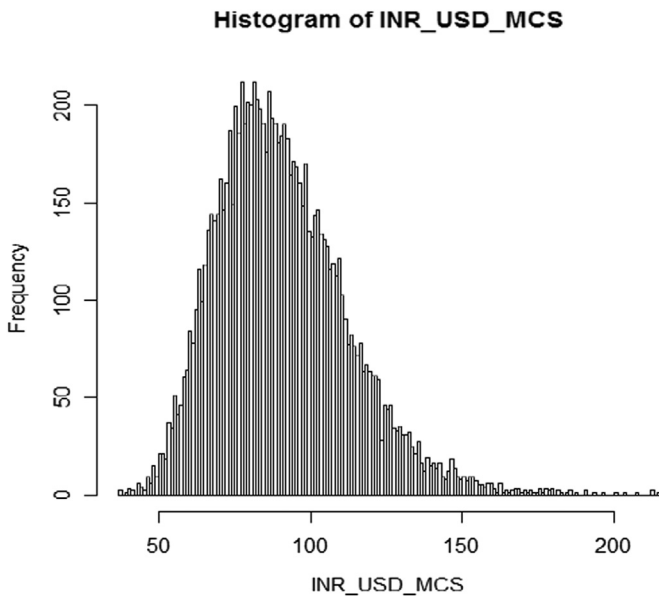


Fig. 3. Histogram of INR–USD forecast in 2024.

OPEX);  $C_T$  is the terminal value of the plant;  $\alpha$  is the tax rate;  $CF$  is the yearly capacity factor (i.e., the plant load factor or PLF);  $x$  is the yearly degradation factor (of the technology); and  $r$  is the cost of capital.

The cost of capital  $r$  is further defined as the leverage-weighted average of the cost of debt and cost of equity (Brealey et al., 2007). That is,

$$r = \frac{D}{D+E}r_D + \frac{E}{D+E}r_E \quad (6)$$

where  $D$  and  $E$  represent the amount of debt and equity, respectively, with  $D/(D+E)$  as the leverage; and  $r_D$  and  $r_E$  are the costs of debt and equity (i.e., rate of equity or ROE), respectively. This shows that, for any fixed leverage, lower costs of debt would translate into a lower cost of capital and, therefore, into a lower LCOE. In fact, in reality, lower cost of debt reduces the cost of capital via an additional mechanism – by increasing leverage given any set of project revenues (Shrimali et al., 2013).

The method for calculating the impact of the FXHF on the LCOE of a representative renewable project is then straightforward, assuming that the only parameter that changes is the debt rate (see Table 6):

- Calculate the baseline LCOE (“A”) of a renewable project using a baseline rate of debt, calculated as the debt rate at market hedging rate. This debt rate is equal to the sum of the rate of the USD loan plus market hedging costs. The typical market cost of currency hedging in India is approximately 7%/year or higher depending on the credit rating of the borrower.<sup>22</sup>
- Calculate the new LCOE (“B”) of a renewable project using a new rate of debt, calculated based on the expected hedging cost from the FXHF. This debt rate is equal to the sum of the debt rate of the USD loan plus expected hedging cost from the FXHF.
- The difference in the two LCOEs ( $C=A-B$ ) provides the reduction in LCOE due to the FXHF.

#### 3.4. Sizing the capital buffer

We note that the FXHF, as discussed so far, is similar to ones discussed in government announcements (Economic Times, 2015).

<sup>22</sup> From Bloomberg Terminal, last accessed in January 2015.

However, this mechanism examines only the expected movements in foreign exchange rates, and ignores two key issues as follows.

First, what would happen in the presence of extreme and unexpected movements in foreign exchange rates? In this case, even if the FXHF is sized to take care of expected movements, the whole FXHF may be wiped out due to unexpected and extreme movements in any particular year. Second, the large difference between the FXHF expected cost and the cost of a market hedge raises questions about what causes the difference and the role of market pricing of the underlying risk (see Section 3.5).

One way to deal with this is for the guarantor (i.e., the government) to take the risk of unexpected and extreme foreign exchange movements in the form of a sovereign guarantee – either explicit or implicit – where the government would cover any shortfalls. Given that such explicit guarantees are not allowed (Ministry Of Finance, 2010), one potential option for providing this guarantee is a capital buffer in a standalone facility, which may be funded by the National Clean Energy Fund (NCEF),<sup>23</sup> for example.

The capital buffer would be the amount needed beyond the FXHF expected (net) payment to ensure that the cumulative (in this case 10-year) default probability of the FXHF is below a pre-specified risk threshold. This capital buffer (size) requirement would depend on the risk exposure that the FXHF is designed to cover – for example, the capital buffer requirement to provide a lower probability of default (for example, 5%, or at P95) would be higher than the capital buffer requirement to provide a higher probability of default (for example, 10%, or at P90).

The cumulative capital buffer for a target deployment capacity of renewable energy can be calculated by calculating the cumulative capital buffer for a typical renewable energy project and then multiplying the latter by the number of typical renewable energy projects that would be deployed to meet the target. For example, if the target is 100 GW and a typical renewable energy project is 50 MW, there would be 2000 renewable energy projects. We calculate the cumulative capital buffer requirements for a typical renewable energy project in the following manner:

- Calculate the yearly INR payments by the FXHF based on the expected values (P50s) of forecasted FX rates. Denote this time series of payments by “A”.
- Calculate the yearly INR payments by the FXHF based on the risk coverage (e.g., P95) of forecasted FX rates. Denote this time series of payments by “B”.
- Calculate the difference time series ( $C=A-B$ ) as the potential net cash outflows from the capital buffer, for the given value of risk coverage.
- The NPV of time series C at the government's cost of capital then provides the capital buffer requirement at time 0.

#### 3.5. The market cost of currency hedging

When the cost of capital of the government is taken as its cost of borrowing – i.e. the cost of risk free security – then it doesn't cost the government anything extra (beyond the expected cost) to maintain the capital buffer for the FX hedging facility. Then, the difference between the market cost of hedging and the FXHF expected cost can be attributed to a combination of factors including: risk-premium, liquidity-premium,<sup>24</sup> and regulation costs.

<sup>23</sup> This is a fund created by levying a tax on coal. The current tax is INR 200/ton, and the current size of the fund is approximately INR 170 billion. See [http://www.business-standard.com/article/economy-policy/national-clean-energy-fund-reaches-rs-17-000-cr-mark-but-not-much-allocated-to-renewable-energy-sector-say-industry-experts-115070200878\\_1.html](http://www.business-standard.com/article/economy-policy/national-clean-energy-fund-reaches-rs-17-000-cr-mark-but-not-much-allocated-to-renewable-energy-sector-say-industry-experts-115070200878_1.html) for more details.

<sup>24</sup> The market charges a liquidity premium for a cross currency swap, which can be derived from the cross currency basis spread.

Risk-premium essentially refers to the fact that the market views FX hedging as a risky activity due to the volatility of FX rate movements and, therefore, the market price of the hedge includes a premium to compensate investors for the risk undertaken; in a way very similar to other risky investments, such as equities. The risk-premium can also be thought of as the premium, over and above the FXHF expected cost, to keep the capital buffer that covers for extreme and unexpected movements in foreign exchange rates.

Liquidity-premium would typically exist in illiquid FX markets, where investors may demand a premium for holding an illiquid asset that is not easily tradable. However, the INR–USD hedge market is fairly liquid up to 10 years and, therefore, a significant liquidity premium is unlikely. Finally, regulation costs are related to costs due to regulations, such as Basel III, which is a comprehensive set of international reform measures for banks, capital requirements. For example, Basel III's credit value adjustment charge (CVA) can add up to 55 basis points to the cost of a 10 year cross currency swap (Risk Magazine, 2012).

We calculate the risk-premium using the standard FX option-pricing theory, as follows. We first find the expected cost of providing a market hedge using option-pricing theory. This includes the risk-premium and, therefore, we call this the *expected market risk adjusted cost* of providing a currency hedge. We then subtract the FXHF expected cost from the expected market risk adjusted cost to find the risk-premium.

To find the risk-adjusted market cost, we model the contract for differences between the FXHF and the developer (or off-taker) as a series of pairs of call and put options at a strike price equal to the initial fixed foreign exchange rate – at 1 USD=63 INR. In each of the 10 call–put pairs, at the strike price of 1 USD=63 INR, the FXHF would sell the developer a call option – the option to buy 1 USD at 63 INR – and the developer would sell the FXHF a put option – the option to sell 1 USD at 63 INR.

The difference between the costs of the call and put options in any particular year, which would be calculated using option-pricing theory, would be the expected risk-adjusted market cost for the contract for that year. The net present value of all the yearly expected risk-adjusted market costs would then provide the expected risk-adjusted market cost for series of pair of options. We use the currency option pricing formulae provided by Biger and Hull (1983) to calculate the cost of call and put foreign exchange options, as follows.

$$C = e^{-r^*T} S \cdot N \left( \frac{\ln(S/X) + [r - r^* + (\sigma^2/2)]T}{\sigma\sqrt{T}} \right) - e^{-rT} X \cdot N \left( \frac{\ln(S/X) + [r - r^* + (\sigma^2/2)]T}{\sigma\sqrt{T}} \right) \tag{7}$$

$$P = C + Xe^{-rt} - Se^{-r^*t} \tag{8}$$

where:

- S: spot price of one unit of foreign currency (USD) on the day of contract – in this case S=INR 63;
- $\sigma^2$ : instantaneous variance of the return on foreign currency (USD) holding – in this case  $\sigma=7.37\%$ ;
- X: exercise price to purchase one unit of foreign currency (USD) – in this case X=INR 63;
- T: exercise date – in this case, T=1, 2, ..., 10;
- r: risk-free rate of interest in the home country (India) – in this case r=7.5%;
- $r^*$ = risk-free rate of interest in the foreign country (US) – in this case  $r^*=2\%$ .

Given this formula, the method for calculating the market cost of providing a currency hedge is as follows:

- Calculate the cost of call options (FXHF cost) for each of the 10 years. Call this time series “A”.
- Calculate the cost of put options (FXHF revenue) for each of the 10 years. Call this time series “B”.
- Calculate the difference time series (C=A–B) to obtain the FXHF net cost.
- Find the NPV of “C” at the risk free rate to obtain the capital buffer requirement. Call this “D”.
- Find the rate of annuity (“E”) on the original loan such that the NPV of the annuity is equal to D.
- “E” is the market cost of providing the currency hedge.

#### 4. Results and discussion

##### 4.1. Foreign exchange forecast for 2015–2024

On the basis of the histograms (e.g., in Fig. 3), we forecast the long term INR–USD foreign exchange rates for every year over 10 years in Table 1. As mentioned earlier, in this paper, we focus on yearly values only. We forecast yearly maximum values of foreign exchange rates to ensure that we represent the worst case values of foreign exchange rates and, therefore, FXHF net payments.

For example, in year 2015, there is a 50% probability (the P50 value) that the INR–USD exchange rate would be 1 USD=65.04 INR or lower, and a 95% probability (the P95 value) that the INR–USD exchange rate would be 1 USD=72.95 INR or lower. The forecast with an associated probability of 50% is taken as the expected foreign exchange rate, which facilitates the calculation of the expected cost of FXHF. The foreign exchange forecasts with other levels, (for example, an associated probability of 95%) facilitate calculations of capital buffer requirements.

##### 4.2. The impact of foreign exchange hedging facility on hedging and levelized costs

We find that the FXHF, with an expected cost of 3.5 percentage points, may reduce the delivered cost of renewable energy by up 9%, via reducing the hedging costs by nearly 50%.

In Section 3, we developed forecasts of the INR–USD foreign exchange rate values using a representative stochastic model. These forecasted values have associated probability levels. As discussed earlier, the foreign exchange forecast with an associated probability of 50% (the P50 level) is the expected foreign exchange rate. Using this expected foreign exchange rate, we now calculate the expected cost of the FXHF, using an example involving a local currency power purchase agreement.

**Table 1**  
Yearly maximum foreign exchange forecast for the period 2015–2024.

Yearly-maximum INR–USD foreign exchange forecast (in INR)				
Year	P50	P75	P85	P95
2015	65.04	68.29	70.03	72.95
2016	67.16	71.9	74.45	78.73
2017	69.33	75.35	78.58	84
2018	71.58	78.77	82.63	89.11
2019	73.91	82.22	86.68	94.17
2020	76.31	85.72	90.78	99.27
2021	78.78	89.3	94.45	104.44
2022	81.34	92.97	99.22	109.71
2023	83.98	96.74	103.59	115.1
2024	86.7	100.62	108.09	120.64



In our example, as is usual practice, a counterparty would take a 10 year USD 10 million loan in 2015 at a fixed interest rate of 5.5%. At the initial INR–USD exchange rate (1 USD=63 INR), this is equivalent to INR 630 million. At the fixed USD interest rate of 5.5%, assuming that the debt is paid back in equal installments, the fixed debt payment obligations are \$1.33 million per year. To mitigate foreign exchange risk, the counterparty enters into a Contract for Differences with the FXHF at a fixed rate of 1 USD=63 INR.

Table 2 shows the payments (or cash flows) between the counterparty and the FXHF, including the FXHF net payments. The first row (“A”) represents the yearly (fixed) payments that the counterparty would make to the FXHF. These correspond to the yearly \$1.33 million obligations converted to INR using the contract for differences contract rate of 1 USD=63 INR. The third row (“B”) represents the expected yearly (variable) payments that the FXHF is expected to make to the counterparty, by converting the yearly \$1.33 million obligation to INR, using the expected foreign exchange rates (based on P50 levels). The fourth row (“C”) – the expected yearly net payments for the FXHF – is the difference between the first two rows.

Assuming a typical INR risk-free rate of 7.5%, the expected cost to the FXHF (*FXHF expected cost*) is the Net Present Value (NPV) of the expected yearly net payments (see Row 3 in Table 2). This is calculated as INR 100.39 million, or approximately 16% of the INR 630 million loan, and (assuming a typical debt to equity ratio of 70:30) approximately 11% of the capital expenditure. At INR 71.3 million/MW (the current capital cost of solar energy), this is approximately INR 7.95 million/MW; and for a 100 GW solar target, approximately INR 795 billion.

Thus, for our INR 630 million loan, the INR 100.39 million, when put in a risk-free account, would take care of the expected devaluation of the INR against the USD under our model. Given that an annuity at 3.5% on the original INR 630 million loan has the same net present value of INR 100.39 million, this indicates that the expected cost of the FXHF is approximately 3.5 percentage points per year.

This FXHF expected cost of 3.5 percentage points can be passed on to the counterparty, resulting in a reduction of approximately 3.5 percentage points in the cost of hedging and, therefore, in the cost of debt. That is, compared to the cost of currency hedging in the market at 7 percentage points, hedging via the FXHF would likely be approximately 50% cheaper. This counterparty is the developer in a local currency (soft) PPA; and we assume that the counterparty would pass the cost onto the off-taker (and, therefore, consumers).

The FXHF would reduce the delivered (i.e., levelized) cost of renewable energy by reducing the cost of capital in two ways: first, via the reduction in the cost of debt itself; and, second, via an increase in the leverage due to a reduction in debt service payments. We calculate the impact on the delivered cost of renewable energy using our cash-flow models (CPI, 2014a). When the expected cost of the FXHF is passed onto the counterparty, if the power purchase agreement is in local currency, the FXHF can reduce the cost of debt by approximately 3.5 percentage points (from 12.5% to 9%) and, therefore, the delivered cost of renewable energy by approximately 9% (see Section 3.3). The gains typically

arise due to substituting expensive equity with cheaper debt; in particular as projects optimize leverage (CPI, 2014a).

#### 4.3. Beyond the expected cost: risk considerations in an FXHF

We find that, to safeguard the FXHF against unexpected and extreme foreign exchange rate movements, a capital buffer is one option to consider. In this case, achieving India's sovereign rating of BBB- would require this buffer to be approximately 30% of the size of the underlying loan; and, the market cost of maintaining this buffer could be as high as 79% of the expected cost.

Table 3 provides the cumulative capital buffer requirements for different 10 year probabilities of default. The capital buffer requirement is zero if the 10 year probability of default is 50% or higher, and the capital buffer requirement increases as the 10 year probability of default goes down. The capital buffer is assumed to be invested in a risk-free INR security.

Based on cumulative default rates of globally rated bonds, for a 10 year probability of default less than 5% (at P95 level of risk coverage), this FXHF would achieve a credit rating equivalent to India's current sovereign rating of BBB- (see Table 5). This is commonly known as breaching the sovereign ceiling, given that risk coverage beyond this level would not be necessary or required.

Assuming this default probability to be less than 5% over the entire tenor of the FXHF (10 years), the required *cumulative* capital buffer is INR 180.04 million – about 1.8 times the expected cost of INR 100.39 million, about 29% of the size of the INR 630 million loan, about 20% of capital expenditure at current capital cost for solar, and about INR 1.16/kWh surcharge. That is, the size of the FXHF, including the expected cost and the capital buffer, would be INR 280.43 million – about 2.8 times the expected cost, about 45% of the size of the loan, and about 30% of the capital expenditure. At current capital costs of solar energy (at INR 71.3 million/MW), for a 100 GW solar target, this translates to approximately INR 2139 billion.

#### 4.4. The market cost of maintaining the capital buffer

We find that the difference between the market cost of currency hedging in and the FXHF expected cost of currency hedging is largely due to the market cost of maintaining a capital buffer.

We calculate the expected market risk adjusted cost as 6.26 percentage points and, therefore, the risk-premium (above the FXHF expected cost) as 2.76 percentage points. This explains most of the difference between the FXHF expected cost of 3.5 percentage points and the cost of currency hedging in the market of 7 percentage points. The remaining 0.74 percentage points can be attributed to liquidity premium as well as transaction costs, such as related to regulations.

Using Eqs. (5) and (6), Table 4 provides the costs of the call (Row 2) and put (Row 3) options for yearly 1 USD=63 INR options. The net present value (at the risk-free rate of 7.5%) of the annual differences between the costs of these 1 USD=63 INR call and put options is INR 138.46. We then calculate the corresponding net costs for the USD 10 million loan, given that the USD 10 million loan would require 10 annual payments of USD 1.33 million. We

**Table 2**  
INR payments by the counterparty and the FXHF.

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Fixed payments from counterparty to FXHF (A)	83.79	83.79	83.79	83.79	83.79	83.79	83.79	83.79	83.79	83.79
Expected foreign exchange rate	65.04	67.16	69.33	71.58	73.91	76.31	78.78	81.34	83.98	86.70
Expected variable payments by FXHF to counterparty (B)	86.50	89.32	92.21	95.20	98.30	101.49	104.78	108.18	111.69	115.31
Expected net payments by FXHF to counterparty (B–A)	2.71	5.53	8.42	11.41	14.51	17.70	20.99	24.39	27.90	31.52

**Table 3**  
Capital buffer requirements for a standalone facility with different probabilities of default.

Probability of default of FXHF	Cumulative capital buffer requirement for 10 years (as % of loan)	Cumulative capital buffer requirement for 10 years (as % of capex)	Cumulative capital buffer requirement for 10 years (INR million/MW)
50%	0	0	0
25%	11.72%	8.20%	5.84
15%	17.95%	12.56%	8.95
5%	28.58%	20.00%	14.26

calculate the net cost of providing the 10 pairs of options for the contract for differences as INR 184.16 (= 138.46 \* 1.33) million.

This INR 184.16 million is equivalent to a 10 year annuity at 6.26 percentage points per year on the original loan amount of INR 630 million. This is essentially the expected market risk adjusted cost, and is 2.76 percentage points higher than the FXHF expected cost of 3.5 percentage points. That is, the risk-premium discovered by option pricing theory is 2.76 percentage points (Table 6).

This indicates the need for sensitivity analysis on the FXHF, in regards to variation of the government's cost of capital, such that it varies from the risk-free rate to the market rate (Table 7). Of course, as the government cost of capital rises, the advantage of the FXHF diminishes.

## 5. Conclusion and policy implications

In this paper, we examine the design of a government-sponsored currency hedging facility, to reduce currency hedging costs, in order to reduce the cost of debt and therefore the delivered cost of renewable energy, thus making renewable energy more competitive and reducing the government's cost of support. In this context, we address the following questions:

- What are the expected costs and related risks of providing such a currency hedging solution?
- How can the government help manage extreme and unexpected movements in foreign exchange rates?
- What is the risk premium in capital markets for taking currency risks?

We analyze this currency hedging facility, assuming that the INR–USD rates follow the typical Geometric Brownian Motion process. We find that the expected cost to provide a currency hedge via the currency hedging facility is 3.5 percentage points, which is close to 50% below market rates. Thus, the hedging facility has the potential to reduce the cost of debt by 3.5 percentage points, which reduces the cost of capital and, therefore, the cost of renewable energy by approximately 9%.

Given the potential to reduce the cost of renewable energy and to make it more competitive, the first policy implication of our study is that the Indian government should consider development of the FXHF. In fact, our discussions with Indian policymakers, such as the Ministry of New and Renewable Energy (MNRE) as well as the India Renewable Energy Development Agency (IREDA), have indicated that they are proactively looking into the

**Table 4**  
Cost of yearly 1 USD=63 INR call and put options.

Time to maturity (in years)	1	2	3	4	5	6	7	8	9	10
Cost of a 1 USD Call option	3.89	6.75	9.34	11.71	13.86	15.81	17.58	19.16	20.58	21.84
Cost of a 1 USD Put option	0.58	0.45	0.32	0.23	0.16	0.11	0.08	0.06	0.04	0.03

**Table 5**  
Average cumulative (10 years') default rates of bonds.

Global rating	Average cumulative (10 years) default rates
AAA	0.78%
AA	0.86%
A	1.77%
BBB	4.88%
BB	15.59%
B	28.70%
CCC/C	51.65%

Source: Standard & Poor's Annual U.S. Corporate Default Study And Rating Transitions

**Table 6**  
Parameters used in LCOE calculations.

Parameter	Value
C (capital expenditure)	INR 7.13 million/MW
D (depreciation)	7% (first 10 years); 3% (from 11th year)
W (operating expenditure)	INR 0.123 million/MW
$C_T$ (termination value)	5% of C
A (tax rate)	33.22%
CF (capacity factor)	19.00%
X (annual degradation factor)	0.70%
$r_D$ (debt rate)	12.50%
$r_E$ (return on equity)	17.30%
DSCR (debt service coverage)	1.3

Source: CPI (2015) and Central Electricity Regulatory Commission.

**Table 7**  
Sensitivity analysis on FXHF.

The government's cost of capital	Cost of maintaining capital buffer	The net cost of hedging via FXHF	Reduction in cost of debt	Reduction in cost of renewable energy
Cost of risk free security (7.5%)	0	3.5% points	3.5% points	9%
8.5%	1% points	4.5% points	2.5% points	6.2%
9.5%	2% points	5.5% points	1.5% points	4%
11%	3.5% points (market cost)	7% points	0	0

development of such an FXHF.

The second policy implication of our study is that the government should be cognizant of the risk exposure of the FXHF and manage it appropriately; for example, via a capital buffer. One way to protect against the risk due to volatile foreign exchange rates is a capital buffer. Based on our model, in order for the FXHF to achieve India's sovereign rating of BBB- in international markets, the cumulative capital buffer requirement would be almost 30% of the corresponding loan amount.

We finally show that the expected cost of the hedging facility doesn't fully take into account the risk-premium that a counterparty in the market would demand for maintaining this capital buffer. Using option pricing theory, we calculate the market risk-premium as 2.76 percentage points, which mostly account for the difference (i.e., 3.5 percentage points) between the cost of currency hedging in the market (i.e., 7 percentage points) and the

expected cost of the FXHF (i.e., 3.5 percentage points).

We note that this paper presents preliminary insights into a government-sponsored currency hedging facility. We acknowledge that our analysis may not fully account for currency fluctuations resulting from catastrophic events (e.g., political and macroeconomic). In particular, we would like to stress that, to the extent that such events are under the government's control, the government can also influence related risks.

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