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Allocating currency risk in renewable power finance: tariff indexation, hedging, and sovereign guarantees

Alma Yerzhanova^{1*}, Coskun Firat², Mukhtar Saltayevich Yerzhanov¹

¹University of Turan, Higher School of Finance and Accounting, Almaty, Kazakhstan

²Istanbul Technical University, Energy Institute, Istanbul, Türkiye

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*Corresponding author

Email address:

al.yerzhanova@turan-edu.kz

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ABSTRACT

Emerging nations' renewable energy investments are frequently hampered by currency risk resulting from the mismatch between local-currency revenues and foreign-currency funding. Though financial hedging, tariff indexation, and sovereign guarantees are often employed to reduce this risk, present studies usually treat these tools separately. Under exchange-rate uncertainty, this study creates a single framework combining all three channels into a unified project-finance model of renewable energy investment. Key features of renewable energy finance are captured by the model, including long-term power purchase agreements, limited hedging markets, and government involvement through guarantees. It defines how, in equilibrium, tariff indexation, private hedging, and government guarantees interact to distribute currency risk among investors, consumers, and the public sector. The research reveals three major observations. Private hedging first reacts endogenously to governmental policy decisions; more indexation or guarantees crowd out financial risk management. Second, while financial hedging rules in deep markets prevail, tariff indexation is somewhat more successful in volatile settings. Third, while sovereign guarantees enhance project bankability, they could transfer risk to public balance sheets. The paper proposes a least-cost risk absorption principle and offers advice on creating currency-risk reduction plans that strike a compromise between fiscal sustainability and investment incentives.

1. Introduction

Emerging economies are generally considered as a key part of worldwide decarbonization plans by increasing renewable energy production [1]. Although many developing nations have plenty of renewable resources and fast-growing electricity needs, financial, rather than technical, considerations limit investment in capital-intensive renewable power projects. Among these limitations, currency risk resulting from the discrepancy between local-currency revenues and foreign-currency funding has become a continual and constraining impediment to investment [2,3]. Emerging markets usually sell renewable energy under long-term power purchase agreements (PPAs) priced in local currency, therefore meeting regulatory goals of cost and macroeconomic stability [4,5]. Project finance also frequently depends on foreign-currency debt because of the comparatively shallow depth of local capital markets and the risk preferences of foreign lenders. This currency mismatch subjects project cash flows to exchange-rate depreciation

risk, therefore raising needed returns and increasing the likelihood of financial hardship. Therefore, otherwise financially viable renewable projects could either fail to reach financial closure or need pricey risk-reduction measures to become bankable [6-8]. Often framed under the idea of "original sin," a large macro-financial literature looks at the causes and results of currency mismatches in developing nations [7,9]. This study highlights the effects on the balance sheet, the way that outside events are made bigger, and the limits on how much money in the local currency can be borrowed over a long period of time. Although these studies offer insightful analysis of the systematic character of currency risk, they usually disregard the project-level financial frameworks and contractual agreements controlling infrastructure investments, including those involving renewable energy projects. Energy economics has a parallel body of research that looks at financing for renewable energy projects, how power markets are set up, and how risky it is to work with rules [10]. This research underlines the need for

dependable regulation, tariff stability, and long-term contracts for drawing in private capital. Many papers in this body of work look at pass-through clauses and tariff indexation as tools to control regulatory uncertainty or inflation risk in PPAs [10-12]. But instead, then being explicitly modeled as a stochastic shock interacting with project financing choices, exchange-rate risk is sometimes handled implicitly or mixed with more general regulatory risk. Practically, government officials and project backers depend on a mix of tools to lower currency risk in renewable energy financing. By tying electricity rates to foreign currencies or price indexes, tariff indexation provisions help to partially transfer exchange-rate risk to customers [13]. While financial hedging tools, like forwards and swaps, let private investors protect themselves against movements in exchange rates, their accessibility and cost are constrained in many developing countries because of illiquidity, counterparty risk, and long maturities [14-16]. Therefore, market inefficiencies as well as risk preferences limit hedging choices.

Another line of research looks at sovereign and multilateral guarantees as ways to get private money moving, especially for investments in things like renewable energy and infrastructure [17-19]. This study shows how, by moving risk from private investors to the public sector, guarantees can lower borrowing rates and raise bankability. Guarantees simultaneously produce contingent financial liabilities and may induce moral hazard by crowding out private risk management [20]. Most studies take either a public finance or development point of view and ignore how guarantees, private hedging activity, and contractual risk-sharing tools work together at the project level. Though tariff indexation, financial hedging, and guarantees are often used, there is no single analytical framework that assesses these tools together in a project-finance environment under exchange-rate risk. Since current research usually analyzes each mechanism separately, it is challenging to compare their relative effectiveness or to evaluate how they work together in distributing currency risk between consumers, investors, and the public sector.

This paper fills this need by creating a project-finance model of renewable energy investment under exchange-rate risk indexing, financial hedging, and national guarantees are clearly shown as different and interacting tools for lowering risk. The renewable power finance model for emerging economies reflects key features such as local-currency revenues, foreign-currency debt, limited hedging markets, and government participation through fiscal and contractual channels. The analysis shows how policy design influences investment incentives and fiscal exposure by incorporating these aspects into a single framework that clarifies how currency risk is distributed among economic actors. The paper offers three major contributions. First, it offers a consistent modeling framework that combines public guarantees, financial hedging, and contract design within a project-finance structure exposed to exchange-rate risk. Second, it produces comparative statics and analytical findings that define the circumstances under which several risk-reduction measures take precedence, overlap, or compete with one another. Third, it provides policy-relevant insights into the cost-effectiveness of different currency-risk

reduction techniques, hence stressing the trade-offs between public financial exposure and private risk management [20,21].

2. Project setting and currency-risk mitigation instruments

Usually under long-term agreements aiming to balance investment incentives, consumer protection, and macroeconomic stability, renewable energy projects in developing nations are constructed. Though nations and technologies vary, these initiatives have a group of institutional aspects that affect their vulnerability to exchange-rate risk and govern the degree of risk reduction. This part covers these characteristics and discusses the primary tools applied in renewable energy financing to handle currency risk.

2.1 Project finance structure and currency mismatch

Project finance is often used to pay for big renewable energy projects. This is when debt payment relies mostly on the money the project makes, not on the sponsor's financial strength [22,23]. Long-term PPAs with utilities or government-backed off takers often provide steady income streams over 15-25 years, hence revenues are usually secured. Although this framework lowers market risk, it also makes projects very sensitive to events influencing debt service ability or cash flows. Reflecting political goals linked to consumer affordability, inflation management, and political acceptability, PPAs in emerging countries are almost always expressed in local currency [5]. In contrast, because of small local financial markets, little availability of long-term local-currency finance, and the presence of foreign lenders [24], a sizable proportion of project debt is denominated in foreign currency. This causes a structural currency mismatch: although part of debt service responsibilities is set in foreign currency, local currency revenues are produced. Exchange-rate depreciation therefore directly weakens project cash flows in foreign-currency terms, raising debt-service ratios and increasing default risk. Unlike diversified corporations, project-financed renewable assets have limited ability to absorb such shocks through internal risk pooling or operational flexibility. As a result, currency risk is a first-order determinant of bankability in emerging-market renewable projects [4].

2.2 Tariff indexation in power purchase agreements

One widely used mechanism to mitigate currency risk is tariff indexation within PPAs. Indexation clauses link electricity tariffs partially or fully to a foreign currency, an exchange-rate index, or an inflation measure correlated with exchange-rate movements [10,11]. By adjusting revenues in response to depreciation, indexation shifts part of the currency risk from investors to electricity consumers or public off takers. Indexation can take several forms, including full foreign-currency denomination, partial indexation of capacity payments, or hybrid structures with caps and floors. These arrangements are often motivated by the desire to improve bankability while limiting the exposure of consumers to exchange-rate volatility. However, tariff indexation may conflict with regulatory goals related to price stability and affordability, particularly in countries with histories of currency crises or high inflation [11].

From a financial standpoint, tariff indexation is a legal risk-sharing system that distributes exchange-rate risk across parties without depending on financial markets. Its efficacy is contingent on political restrictions, regulatory integrity, and demand elasticity as well as on demand elasticity. Though often used in practice, few frameworks for project-finance include clearly the tariff indexation.

2.3 Financial hedging and market friction

Financial hedging using derivatives including forwards, swaps, and options offers another way to control currency risk. In theory, private hedging lets project backers protect themselves against currency fluctuations without burdening consumers or the government sector with risk. But in fact, in many developing countries, hedging markets are shallow, illiquid, and have high transaction costs [25]. Few long-term currency hedges correspond with the length of renewable PPAs, and rollover approaches subject initiatives to basis risk and liquidity shocks [14,15]. Further increasing hedging expenses are counterparty risk, legal limitations, and low participation from local financial institutions. Therefore, hedging premiums tend to rise nonlinearly with maturity and coverage, making total hedging far too pricey for many infrastructure projects [15,16]. These market inefficiencies suggest that structural and financial constraints, rather than risk preferences alone, limit hedging choices. In the realm of project finance, hedging influences financing conditions and default probabilities, hence generating interactions between contract design and financial risk management that are sometimes overlooked in current models.

2.4 Sovereign and multilateral guarantees

A third class of tools reduces currency risk by moving losses to the public sector via sovereign or multinational guarantees. Such promises could address convertibility and transfer risks, debt service shortages, or currency rate fluctuations exceeding a specified level [18]. Guarantees help to reduce borrowing expenses and draw in international money that would normally stay on the sidelines by raising the risk profile of projects. Guarantees, though, generate potential fiscal obligations that could show up during times of economic turbulence, just when government finances are strained [18,20]. Underpriced or poorly focused guarantees might push out private risk management and foster too much borrowing in foreign currencies. The financial consequences of assurances therefore rely heavily on how they interact with other instruments for lowering risk as well as with personal hedging behavior [18,19]. Although guarantees are frequently studied from a public finance or institutional point of view rather than from within a project-level cash-flow model including default risk and private incentives, they are quite important in renewable energy policy and development finance.

2.5 Motivation for a unified modeling framework

The foregoing analysis makes clear how guarantees, financial hedging, and tariff indexation interact as tools to distribute currency risk across consumers, investors, and the public sector. Although their interactions are unknown, these tools are commonly used simultaneously in reality. Policies that increase guarantees may lower incentives to hedge; yet, high indexation might change the best size and currency distribution of project funding. This paper develops a unified

project-finance framework that explicitly incorporates these instruments and analyzes how they jointly determine currency-risk allocation and investment outcomes. By modeling tariff indexation, hedging, and guarantees within a single structure, the analysis provides a consistent basis for comparing their effectiveness and fiscal implications under exchange-rate uncertainty.

3. A unified project-finance model under exchange-rate risk

This section develops a project-finance model of renewable power investment under exchange-rate risk. The model captures the key features discussed in Section 2 and provides a unified framework for analyzing tariff indexation, financial hedging, and sovereign guarantees as alternative and interacting currency-risk mitigation instruments.

3.1 Timeline and economic environment

Time is discrete and indexed by $t=0,1,\dots,T$. At $t=0$, a renewable power project is developed and financed. At $t\geq 1$, the project generates electricity, earns revenues, and services debt. The project is financed using a standard project finance structure [22]. Let total investment cost be normalized to one. A fraction $\lambda\in(0,1)$ is financed with debt, while the remainder is financed with equity. Debt has fixed contractual repayments denominated in foreign currency. The exchange rate at time t , denoted S_t , is defined as units of local currency per unit of foreign currency. A higher value of S_t therefore represents a depreciation of the local currency. The exchange rate follows a stochastic process:

$$S_t = \bar{S} \cdot \varepsilon_t \tag{1}$$

where \bar{S} is the expected exchange rate and ε_t is a mean-one stochastic shock with support on \mathbb{R}_+ . The distribution of ε_t captures exchange-rate volatility and tail risk is commonly observed in emerging markets [2,3,26].

Figure 1 illustrates how exchange-rate shocks (ε_t) propagate through project cash flows in a renewable energy project-finance structure. Exchange-rate movements affect revenues through tariff indexation (α) and debt service through financial hedging (h), while residual currency risk may be absorbed by the public sector via sovereign guarantees (g). These mechanisms determine the allocation of currency risk among investors, consumers, and the public sector. Table 1 summarizes the key model variables and clarifies their economic interpretation within the project-finance framework.

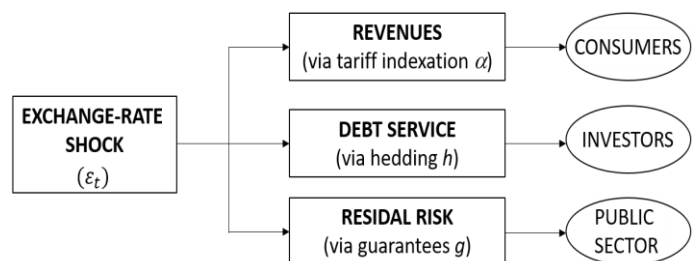


Figure 1. Currency risk allocation in renewable energy project finance

Table 1. Key model variables and economic interpretation

Symbol	Description	Economic role
α	Tariff indexation	Consumer risk absorption
h	Hedging coverage	Private risk management
g	Guarantee intensity	Public risk absorption
ε_t	Exchange-rate shock	Source of uncertainty

3.2 Revenues and tariff indexation

At each $t \geq 1$, the project produces a fixed quantity of electricity, normalized to one. Electricity is sold under a long-term power purchase agreement (PPA) at a base tariff p , denominated in local currency. Tariff indexation is modeled through a parameter $\alpha \in [0,1]$, which measures the degree to which revenues adjust to exchange-rate movements. Local-currency revenues at time t are given by:

$$R_t = p \cdot [(1 - \alpha) + \alpha \cdot \varepsilon_t] \tag{2}$$

When $\alpha=0$, tariffs are fully fixed in local currency and revenues are insensitive to exchange-rate fluctuations. When $\alpha=1$, revenues are fully indexed to the exchange rate. Intermediate values of α capture partial indexation, caps, or hybrid tariff structures commonly observed in practice [10,11].

3.3 Debt service, currency mismatch, and default

Debt service obligations are denominated in foreign currency. Let d denote the fixed foreign-currency debt payment due each period. The corresponding local-currency debt service at time t is:

$$D_t = d \cdot S_t = d \cdot \bar{S} \cdot \varepsilon_t \tag{3}$$

The project faces limited liability. Default occurs whenever project revenues net of risk-mitigation instruments is insufficient to meet debt service. Formally, default occurs at time t if:

$$\tilde{R}_t < \tilde{D}_t \tag{4}$$

where \tilde{R}_t and \tilde{D}_t denote effective revenues and effective debt service after accounting for tariff indexation, hedging, and guarantees, defined below.

Default results in the loss of project value and imposes costs on lenders and, potentially, the public sector. Equity holders receive zero payoff in default states. These features reflect standard assumptions in project-finance modeling [4,8]. Default is modeled as a reduced-form, binary event occurring whenever project cash flows are insufficient to meet debt service in a given period. The model abstracts from recovery values, debt renegotiation, and dynamic restructuring. While these features matter for valuation, their omission allows the analysis to focus transparently on the allocation of exchange-rate risk and on the comparative effectiveness of alternative risk-mitigation instruments, which are the central objects of interest.

3.4 Financial hedging

Project sponsors may hedge a fraction $h \in [0,1]$ of foreign-currency debt service using financial derivatives. Hedging reduces exposure to exchange-rate shocks but entails costs reflecting market friction, illiquidity, and maturity mismatch [14-16]. Effective debt service after hedging is given by:

$$\tilde{D}_t = (1 - h)D_t + h \cdot d \cdot \bar{S} \tag{5}$$

The hedged portion of debt service is fixed at the expected exchange rate, while the unhedged portion remains exposed to exchange-rate shocks. The cost of hedging is represented by a convex cost function

$$C(h), C(0) = 0, C'(h) > 0, C''(h) > 0 \tag{6}$$

Capturing the increasing marginal costs of hedging at higher coverage levels due to limited market depth and counterparty constraints [14-16]. Hedging costs are incurred by the project sponsor and reduce expected project value.

3.5 Sovereign guarantees

The government may provide a sovereign guarantee covering a fraction $g \in [0,1]$ of debt service shortfalls arising from exchange-rate movements. Guarantees are triggered in states where revenues fall short of debt obligations. Effective debt service after guarantees is defined as:

$$\tilde{D}_t^g = (1 - g)\tilde{D}_t \tag{7}$$

The guaranteed portion $g\tilde{D}_t$ is effectively absorbed by the public sector. Guarantees reduce default risk and improve project bankability but generate expected fiscal costs. Let the expected fiscal cost of guarantees be denoted $F(g)$, where $F'(g) > 0$ and $F''(g) \geq 0$, reflecting increasing fiscal exposure and distortionary costs of public risk absorption [18,20]. Guarantees are assumed to be credible within the relevant policy range, though credibility constraints are discussed later.

3.6 Project payoffs

Project profits in period t are given by

$$\Pi_t = \begin{cases} R_t - \tilde{D}_t^g, & \text{if } \tilde{R}_t \geq \tilde{D}_t^g \\ 0, & \text{otherwise} \end{cases} \tag{8}$$

Expected project value at $t=0$ is

$$V(\alpha, h, g) = \mathbb{E}[\sum_{t=1}^T \beta^t \Pi_t] - C(h) \tag{9}$$

where $\beta \in (0,1)$ is the discount factor.

Higher values of α , h , and g reduce exchange-rate exposure but shift risk across consumers, investors, and the public sector in different ways.

3.7 Government and private sector decisions

The model features a two-stage decision structure.

Government stage: To guarantee project bankability and reduce financial risk, the government is supposed to choose tariff indexation α and promise intensity g . Formally, the government minimizes expected fiscal costs subject to institutional feasibility restrictions [18] and the participation participation of the lender.

$$\min_{\alpha, g} F(g) \quad \text{s.t.} \quad \mathbb{E}[V_L(\alpha, h^*(\alpha, g), g)] \geq 0, \quad \alpha \in [0, \bar{\alpha}], g \in [0,1]. \tag{10}$$

Where:

- V_L = lender expected payoff
- $h^*(\alpha, g)$ = private hedging response

Private sector stage: Given (α, g) , the project sponsor chooses hedging coverage h to maximize expected project value $V(\alpha, h, g)$, subject to market frictions [14-16]. This structure captures the interaction between public policy and private risk management in renewable project finance.

3.8 Equilibrium

An equilibrium is defined as a triple (α^*, h^*, g^*) such that:

- h^* maximizes $V(\alpha, h, g)$ given (α^*, g^*) ,
- (α^*, g^*) solve the government’s fiscal-cost minimization problem subject to project bankability and regulatory constraints, taking into account the endogenous hedging response $h^*(\alpha, g)$,
- lenders’ participation constraints are satisfied.

The equilibrium allocation determines how currency risk is distributed among investors, consumers, and the public sector.

3.9 Discussion

The model nests several special cases studied in the literature, including pure tariff indexation ($h = g = 0$), pure financial hedging ($\alpha = g = 0$), and pure public risk absorption ($\alpha = h = 0$). By allowing all three instruments to operate simultaneously, the framework provides a unified basis for analyzing currency-risk mitigation strategies in renewable power finance. This reduced-form policy objective reflects a fiscally conservative government that only uses tariff indexation and guarantees to the degree necessary to restore project bankability, therefore disregarding more general welfare or distributional concerns.

4. Results

This section analyzes how tariff indexation, financial hedging, and sovereign guarantees allocate exchange-rate risk in equilibrium. The focus is on stylized comparative statics, dominance regions, and interaction effects implied by the structure of the model, rather than on calibration to specific countries or closed-form solutions. The results highlight qualitative relationships that are robust across a broad class of exchange-rate processes, convex hedging cost functions, and settings consistent with Section 3. Table 2 summarizes the main stylized results (SR) derived from the model and serves as a guide to the analysis presented in Sections 4.1–4.4.

Table 2. Summary of stylized results

Results	Instrument	Main implication
SR1	Hedging	Crowded out by tariff indexation (α) and guarantees (g)
SR2	Indexation vs. hedging	Existence of a volatility threshold
SR3	Guarantees	Fiscal risk and crowding-out of private instruments
SR4	All instruments	Least-cost allocation of currency risk

4.1 Hedging behavior given public policy

We begin by characterizing the project sponsor’s optimal hedging decision, taking tariff indexation α and guarantee intensity g as given.

Stylized Result 1: Optimal hedging response

For given (α, g) , the optimal hedging coverage h^* satisfies the first-order condition

$$C'(h^*) = \mathbb{E}[\beta^t \cdot d \cdot \bar{s} \cdot \varepsilon_t \cdot 1\{\tilde{R}_t \geq \tilde{D}_t^g\}] \tag{11}$$

provided an interior solution exists. Higher tariff indexation (α) or stronger guarantees (g) weakly reduce optimal hedging demand.

Hedging trades off a convex cost against reduced exposure to exchange-rate shocks. Tariff indexation stabilizes revenues by shifting part of the risk to consumers, while guarantees reduce effective debt service in adverse states. Both mechanisms compress the distribution of project cash flows, lowering the marginal benefit of private hedging and leading to partial or complete crowding-out of financial risk management when public or contractual protection is strong [14-16].

4.2 Indexation versus hedging: a threshold comparison

We next compare tariff indexation and financial hedging as alternative instruments for mitigating currency risk.

Stylized Result 2: Indexation–hedging dominance

For a broad class of exchange-rate distributions and convex hedging cost functions, there exists a threshold level of exchange-rate volatility σ^* such that:

- for $\sigma < \sigma^*$, private hedging dominates tariff indexation as the least-cost risk-mitigation instrument;
- for $\sigma \geq \sigma^*$, tariff indexation dominates hedging in reducing default risk.

The threshold σ^* is decreasing in hedging costs and increasing in regulatory tolerance for tariff variability.

At low volatility, hedging markets can absorb exchange-rate risk efficiently at relatively low cost. As volatility increases, hedging premiums rise nonlinearly due to market frictions and maturity mismatch, while tariff indexation provides direct and state-contingent risk sharing without reliance on financial intermediaries. This comparison formalizes why indexed PPAs are more prevalent in environments characterized by high exchange-rate volatility [10,15].

4.3 Guarantees and crowding-out effects

We now turn to the role of sovereign guarantees.

Stylized Result 3: Guarantee crowding out

An increase in guaranteed intensity g weakly reduces both optimal hedging h^* and optimal tariff indexation α^* . For sufficiently high values of g , private risk-mitigation instruments may be fully crowded out.

Guarantees insure lenders against downside risk and compress the distribution of debt-service outcomes. This weakens the sensitivity of default probabilities to exchange-rate shocks and reduces incentives for both private hedging and contractual risk sharing. While guarantees improve bankability, they shift currency risk to the public balance sheet and may displace lower-cost private instruments when not carefully targeted [18,20].

4.4 Least-cost risk absorption

To evaluate the efficiency of alternative instruments, consider the total expected cost of currency-risk mitigation, defined as the sum of:

- private hedging costs,
- expected consumer transfers from indexation,
- expected fiscal costs of guarantees.

Stylized Result 4: Least-cost risk absorption principle

In equilibrium, exchange-rate risk should be allocated to the agent with the lowest marginal cost of risk absorption:

- consumers via tariff indexation when pass-through costs are low,
- investors via hedging when financial markets are deep,
- the public sector via guarantees only when private instruments are prohibitively costly.

Mixed regimes arise when marginal costs are comparable.

No single instrument dominates universally. Efficient policy minimizes total economic cost by assigning risk to the agent best equipped to bear it. Guarantees are welfare-improving when they compensate for missing markets, but inefficient when they displace functioning private risk-management mechanisms [18,20].

4.5 Interaction effects and non-linearities

The interaction between instruments generates non-linear effects that are absent in partial-equilibrium analyses.

Stylized Result 5: Non-linear interaction effects

The marginal effectiveness of any risk-mitigation instrument is decreasing in the intensity of the others. In particular:

- indexation reduces the marginal benefit of hedging,
- hedging reduces the marginal value of guarantees,
- guarantees flatten the payoff from both private instruments.

All three instruments operate on the same underlying exchange-rate shock. As one instrument absorbs more risk, residual exposure declines, lowering the returns to additional mitigation. This explains why “stacking” multiple instruments often yields diminishing returns in practice.

4.6 Project viability and financing constraints

Finally, we characterize conditions under which renewable projects become bankable.

Stylized Result 6: Bankability condition

There exists a minimum combined level of risk mitigation (α, h, g) such that the lender’s participation constraint is satisfied. In high-volatility environments, project bankability typically requires:

- high tariff indexation,
- substantial guarantees,
- or a combination of partial hedging and public support.

Currency risk directly affects debt-service capacity. When hedging markets are shallow and tariff flexibility is constrained, achieving bankability without some form of public or contractual risk sharing may be infeasible, even for economically efficient projects [4,8].

5. Comparative statics and extensions

This section looks at how equilibrium results change with important structural factors and discusses a few changes that improve the model without changing its basic logic. The aim is to explain how regulatory constraints, financial market conditions, and variations in exchange-rate risk affect the optimal mix of currency-risk management strategies.

5.1 Exchange-rate volatility

Imagine that the expected exchange rate remains constant while the variance of exchange-rate shocks ε_t rises. Higher volatility raises the possibility of significant depreciation events and exacerbates project cash flow downside risk. A rise in exchange-rate volatility does not uniformly increase the marginal benefit of every risk-reducing tool; rather, it does so asymmetrically. Convex hedging costs and little market depth make financial hedging more and more costly; tariff indexation offers linear and state-contingent protection against depreciation. Higher volatility thus drives equilibrium results toward more dependency on tariff indexation and, when regulatory restrictions bind, toward public guarantees. This comparative static is in line with the actual frequency of indexed PPAs in volatile settings and shows basic variations in how contractually and financial instruments handle exchange-rate risk.

5.2 Hedging market depth and cost

Think next about a cut in hedging expenses, shown by a drop in the marginal cost curve $C'(h)$. This change can point to stronger derivative markets, better counterparty creditworthiness, or the arrival of long-term institutional investors. Reduced equilibrium reliance on tariff indexation and guarantees results from higher optimal private hedging coverage brought on by lower hedging costs. In the limit, public risk absorption becomes pointless since private risk management completely internalizes exchange-rate risk when hedging markets are smooth. This finding emphasizes the significance of financial market development as a strong but indirect influence on the results of renewable investments. By lowering borrowing costs without raising public exposure, better hedging market depth can replace explicit contractual or financial risk sharing [14-16].

5.3 Regulatory constraints on tariff adjustment

In several growing economies, political or legal restrictions restrict the level of tariff indexation that can be carried out. Affordability issues, inflation targeting systems, or distributional concerns [27] could cause these restrictions. Including an upper limit $\bar{\alpha} < 1$ on tariff indexation limits the capacity of the project to pass exchange-rate risk to consumers. When such restrictions bind, equilibrium results lean toward more reliance on financial hedging and government guarantees. In volatile situations, binding tariff restrictions can cause guarantees to be the second-best option for regaining bankability even if they are expensive for the government. This conclusion highlights how closely fiscal policy and energy regulation are linked and helps to explain why nations with rigid tariff systems sometimes rely more heavily on government de-risking tools [10,11].

5.4 Sovereign risk and guarantee credibility

The baseline model treats guarantee as fully credible. In practice, their effectiveness depends on government capacity and national creditworthiness. Lower guarantee credibility raises the residual exposure lenders bear and lessens their capacity to manage default risk. As trust falls, balance moves from public risk absorption toward private tools even if these are expensive. In some instances, a lack of confidence might make guarantees useless, which would make a project impossible to complete even if the public were in favor of it. This study shows that assurances are not ideal replacements for financial market growth and that poor government balance sheets could negate the efficiency of de-risking plans [18-20].

5.5 Extension: endogenous debt currency composition

The model so far assumes the currency makeup of debt as independent. One key extension lets the project sponsor decide whether to borrow in local currency or in foreign currency. Sponsors must balance more significant interest expenses with less exposure to currency rate fluctuation when local-currency debt is offered at a premium. Local-currency borrowing becomes more appealing when volatility is high, there is little tariff indexation, and guarantees are weak. Deep hedging markets favor foreign-currency debt. This extension highlights the main point of the paper: tools to reduce currency risk affect not just how risk is allocated but also the basic structure of project financing.

5.6 Extension: auction and PPA design

Still another extension looks at how PPA award systems and renewable energy auctions work together to reduce currency-related risk. Rules for auctions that say how to use indexes, which currency to use, or who can get guarantees, basically commit in advance how exchange rate risk will be split up. The model forecasts that flexible risk-sharing auction designs draw lesser bids by lowering needed risk premia but could raise long-run consumer or financial exposure. Conversely, strict auction systems discourage involvement and increase borrowing rates while reducing public risk. These trade-offs suggest that auction and contract design should account for broader macro-financial conditions rather than treating currency risk as a purely sectoral issue.

6. Policy discussion and implications

The model developed in this paper yields several implications for the design of renewable energy policies in emerging markets. Rather than advocating a single risk-mitigation instrument, the analysis highlights how currency risk should be allocated to the agent, which is best able to absorb it at least cost, subject to institutional and political constraints. This section discusses the implications for energy regulators, finance ministries, and development finance institutions.

6.1 Implications for PPA and tariff design

One first implication is in the way power purchase contracts are drafted. The model indicates that in highly volatile situations, especially when hedging markets are weak, tariff indexation can be a good way to lower exchange-rate risk. Indexation lowers default risk and enhances bankability by stabilizing project revenues. However, tariff indexation could undermine affordability and inflation goals and transfers currency risk to customers or public off takers. This compromise implies that full foreign-currency denomination is not always preferable; instead, partial and well-thought-out indexation systems are usually preferred. Extreme price changes can be limited by indexation caps, floors, or asymmetrical pass-through policies, which would also offer investors protection from losses. Energy economics research shows that these points are in line with rules and contract-design insights.

6.2 Financial market development as energy policy

The data highlights the need for financial market growth as a minor but very effective driver of renewable energy investment. Deep and liquid currency-hedging markets enable private investors to manage exchange-rate risk at a very low cost, therefore lowering reliance on public guarantees and tariff indexation. Therefore, policies that encourage investor participation, improve counterparty creditworthiness, or support longer-dated derivative markets

can enhance renewable investment outcomes without increasing financial risk. From this angle, energy policy can be seen as coordination between financial authorities and energy regulators insofar as it lowers borrowing expenses and increases the possible range of risk-sharing agreements [14-16].

6.3 The role and limits of sovereign guarantees

Particularly in nations with significant exchange-rate volatility and limited private risk-management options, sovereign and multinational guarantees are quite important for inspiring renewable investment in many developing economies. The model supports the idea that guarantees may help to restore bankability by reducing required returns and compressing downside risk, therefore enhancing it. The research also emphasizes significant restrictions at the same time. Guarantees could push out private hedging and contractual risk sharing, therefore transferring currency risk onto the public balance sheet. Guarantees can promote excessive foreign currency borrowing and produce large contingent fiscal liabilities when they are either undervalued or widely used. These hazards highlight the need of focused, open, and conditional guarantee design in line with the public finance literature on fiscal risk management.

6.4 Implications for development finance institutions

In renewable energy initiatives, development finance institutions (DFIs) sometimes act as policy advisors, lenders, and guarantors. The model implies that the most value from DFIs comes from interventions that support rather than supplant private risk management. Instruments that share risk only in rare cases, spur private hedging markets, or help with legal changes may be more important than blanket guarantees that cover a lot of currency risk. Furthermore, the framework emphasizes the need to align local capacity with appropriate de-risking tools. In areas where fiscal capacity is scarce or regulatory reliability is low, too much reliance on guarantees could jeopardize long-term sustainability, even if short-term investment rises. Emerging countries' policy-oriented assessments of clean energy finance concur with these observations [28,29].

6.5 Integrated policy design

A major conclusion of the article is that in order to reduce currency risk in renewable energy financing, an all-encompassing policy approach is needed. Financial regulation, fiscal policy, and tariff design interact to define at what price risk is assigned and how it is distributed. Policies concentrating closely on one instrument run the risk of transferring costs among agents without lowering total exposure. The most promise for increasing renewable investment while maintaining fiscal and regulatory stability comes from an integrated strategy including mild tariff indexation, market-based hedging, and well-crafted public support. The model offers a clear approach for assessing such policy bundles and for modifying them to fit the macroeconomic financial situation of individual nations.

7. Conclusion

This article presents a single project-finance model for emerging-market renewable energy investments that examines currency risk. Driven by the continuous gap between local-currency income and foreign-currency finance, the approach combines tariff indexation, financial hedging, and national guarantees as substitute and interacting means of assigning exchange-rate risk. The study reveals a few fundamental truths. To begin with, private risk management

reacts endogenously to public policy decisions: higher tariff indexation or stronger guarantees discourage financial hedging. Second, in high-volatility situations, especially when long-term hedging markets are weak, tariff indexation seems to be a rather good tool. Third, sovereign guarantees make a project more likely to be approved, but they can also push out private ways to lower risk and move currency risk onto the government's balance sheet. These data show that tools for currency-risk reduction cannot be assessed on their own. The paper's main contribution is the formulation of a principle of least-cost risk absorption. Subject to regulatory and legal constraints, effective policy assigns exchange-rate risk to the agent, investors, consumers, or the public sector, with the lowest marginal cost of bearing it. This perspective helps explain the diversity of risk-sharing arrangements observed across developing economies and highlights the trade-offs inherent in renewable energy policy design. The framework also stresses how closely energy policy, financial market development, and fiscal policy are related. Policies strengthening hedging markets or improving regulatory credibility can lessen reliance on overt government assurances, therefore lowering fiscal exposure while maintaining investment incentives. Conversely, strict tariff systems or weak financial institutions could demand more public engagement, even at a higher long-run cost. The report has a few flaws. The model concentrates on general mechanisms and comparative statics rather than on country-specific institutional nuances or empirical calibration, hence abstracting from them. Also covered in condensed form are political economic restrictions and interactions with other sources of uncertainty, including demand or regulatory risk. These simplifications are made on purpose so that the study can show the basic trade-offs instead of making exact numerical predictions. Further studies might direct the framework in a number of ways. Using project-level data, empirical studies might evaluate the model's predictions and determine the comparative costs of different risk-reduction measures. More theoretical extensions might include dynamic investment choices, internal knowledge of exchange-rate risk, or interactions between currency risk and more general economic shocks. Such studies would help to guide plans to increase renewable energy investment in developing countries while controlling monetary and tax risks.

Ethical issue

The authors are aware of and comply with best practices in publication ethics, specifically concerning authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. The authors adhere to publication requirements that the submitted work is original and has not been published elsewhere in any language.

Data availability statement

The manuscript contains all the data. However, more data will be available upon request from the corresponding author.

Conflict of interest

The authors declare no potential conflict of interest.

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