Cobalt Governance and Strategic Power: A Hamiltonian Intertemporal Analysis of Export Suspension in the DRC

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Abstract

In a context of sustained price decline and heightened volatility in the global cobalt market, the Democratic Republic of the Congo (DRC)—the world's leading producer—suspended its cobalt exports in February 2025. This decision aimed to recalibrate international prices, reinforce mineral sovereignty, and initiate a structural transformation of the domestic value chain. Against this backdrop, the objective of this article is to assess the economic sustainability of such a strategy by employing a dynamic framework of intertemporal trade-offs between short-term losses and long-term gains.

The adopted methodology relies on a rigorous analytical model grounded in the Hamiltonian formalism, allowing the modeling of economic flows weighted by the policymaker's time preference factor. The findings suggest that while the suspension generates a negative welfare balance in the short term, a favorable reversal remains attainable in the medium term, provided that local transformation, institutional reforms, and bilateral cooperation are rapidly activated.

Accordingly, it is recommended that the DRC adopt a strategy of patient statecraft, characterized by a low discount rate, accelerate the implementation of industrial reforms such as local refining and supply chain traceability, establish a contract-based governance framework through structured dialogue between the state and mining operators, and formalize a bilateral partnership with Indonesia to exert coordinated influence on global pricing. In this perspective, cobalt must no longer be viewed as a mere strategic commodity, but rather as a sovereignty lever to be governed intertemporally through coherent and forward-looking economic policy.

Keywords: Cobalt, Export Suspension, Hamiltonian Model, Intertemporal Trade-off, Resource Governance, Mining Policy.

JEL Classification: C61, D90, F13, Q34, Q31, 025

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1. Introduction

The Democratic Republic of Congo (DRC), as the world's leading producer of cobalt—accounting for nearly 78% of global output in 2024[2]—finds itself at the crossroads of a major strategic dilemma. On the one hand, it controls one of the critical inputs of the global energy transition, essential to produce lithium-ion batteries used in electric vehicles, electronic devices, and energy storage systems. On the other hand, this dominant position has not yet translated into a structural appropriation of the value chain, nor into the optimal capture of economic returns at the national level. In fact, price volatility, governance failures in export circuits, and the predominance of foreign refiners constitute major obstacles to maximizing the domestic economic multiplier of this mineral rent (Auty & Furlonge, 2019).

It is within this context of structural imbalance that the DRC's Authority for the Regulation and Control of Strategic Mineral Substances Markets (ARECOMS)[3] decided, on February 22, 2025, to suspend cobalt exports for a four-month period. Unprecedented in the sector's history, this regulatory measure was adopted unilaterally, without prior consultation with economic operators, triggering strong reactions both domestically and internationally. Officially, the decision aimed to fulfill three objectives: restore price stability, reorganize commercialization channels, and promote local value addition. However, the measure was also interpreted as a break from extractivist legacies, reflecting the Congolese State's growing desire to reassert mineral sovereignty in a globalized environment.

The immediate impact on the markets was substantial: cobalt prices surged, underscoring the structural dependence of global supply chains on Congolese production. While some interpreted this as a successful demonstration of scarcity leverage, others questioned the sustainability of such an approach. Indeed, the export suspension raises concerns about contract continuity, the strategic responses of industrial actors, and the limits of supply-side shock regulation. In this light, the DRC appears to be entering a new geoeconomic phase, where the objective is less about exporting volume than about exerting price influence—a shift that requires a redefinition of both instruments and strategic positioning.

It is also important to note that this initiative emerged against a backdrop of adverse market conditions: between January 2023 and late 2024, cobalt prices fell by more than half, from $50,000 to less than $25,000 per ton[4]. This prolonged decline was primarily driven by poorly regulated supply surpluses, including the rapid expansion of artisanal mining in the DRC, as well as the emergence of new producers such as Indonesia, whose High-Pressure Acid Leaching (HPAL) projects have significantly increased cobalt hydroxide output. Consequently, the suspension may be viewed as a market rebalancing attempt via a deliberate contraction of supply—an act of stabilization through flow compression, aimed at regaining control over price-quantity adjustment dynamics.

Beyond this short-term correction, the suspension appears to signal a more structural ambition: the imposition of a new regulatory paradigm for the cobalt sector. By intentionally disrupting export flows, the State seeks to redefine the rules of the game surrounding traceability, contractual governance, and local value integration. In this context, the suspension becomes a veiled instrument of industrial policy, designed to trigger leverage effects on domestic transformation investments (Fliess *et al.*, 2017; Östensson, 2020; Terzi *et al.*, 2022; Fang, 2024). It also serves as a diplomatic lever (Vandome, 2023; Surya, 2023; Humphreys, 2024), enabling the DRC to reposition itself within global conversations on critical value chains, particularly regarding ESG standards, mineral sovereignty, and African industrialization.

However, this strategy is not without short-term collateral effects. The suspension has caused a substantial loss in fiscal revenues, a deterioration in the balance of payments, and mount pressures on mining operators,

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[2] *Fastmarkets, Cobalt export suspension by DRC shakes global market*

[3] ARECOMS, *Décision n°001/ARESCOMS/2025 du 22 février 2025 portant suspension temporaire de l'exportation du cobalt de la RDC*

[4] *London Metal Exchange*

particularly SMEs, facing stock immobilization and contract breaches. On a macroeconomic level, the contraction in exports has led to a depletion of foreign reserves and currency depreciation, with potential inflationary spillovers (Christensen, 2016; Pinshi, 2018; Gumata *et al.*, 2019). In a context already marked by budgetary constraints and social tensions, such shocks further narrow the State's room for maneuver to implement structural reforms.

Moreover, recent analyses suggest a risk of technological disintermediation: by attempting to manipulate prices, the DRC may inadvertently accelerate investment in cobalt-free battery technologies such as Lithium-Iron-Phosphate (LFP) (Tan & Keiding, 2023), which are increasingly favored by Asian manufacturers (Lee & Manthiram, 2022). Such substitution would weaken the strategic position of Congolese cobalt and limit the country's long-term capacity to capitalize on this resource.

Conversely, the strategic rationale behind the move deserves closer attention. Drawing inspiration from the OPEC model, this approach seeks to elevate the DRC's status from a passive price-taker to an active price-maker. Yet, to achieve meaningful influence over global pricing, the strategy must be accompanied by robust management, sustained dialogue with industrial stakeholders, and the capacity to absorb transitional shocks. While the DRC remains central in terms of volumes, its ability to shape exchange terms will ultimately depend on embedding its mining policy within a cooperative and predictable framework.

In this context, the emergence of alternative proposals—such as the implementation of Voluntary Export Restraints (VERs)[5] (Tarr, 1989) or export duties—signals a transition toward more nuanced regulatory tools that balance sovereignty imperatives with market constraints. Similarly, ongoing negotiations with Indonesia, the world's second-largest cobalt producer, could pave the way for a coordinated governance framework for critical metals markets, reminiscent of multilateral arrangements in the petroleum sector.

Thus, two key questions arise: Is the DRC undertaking a long-term geoeconomic shift capable of redefining the rules of trade for critical minerals? Or could this rupture strategy backfire in the absence of the necessary structural reforms? To address this inquiry, the present study adopts a two-pronged analytical approach: first, a factual assessment of cobalt price dynamics and the immediate effects of the export suspension; second, a formal analytical framework based on the Hamiltonian model to evaluate the intertemporal trade-off between immediate losses and future gains.

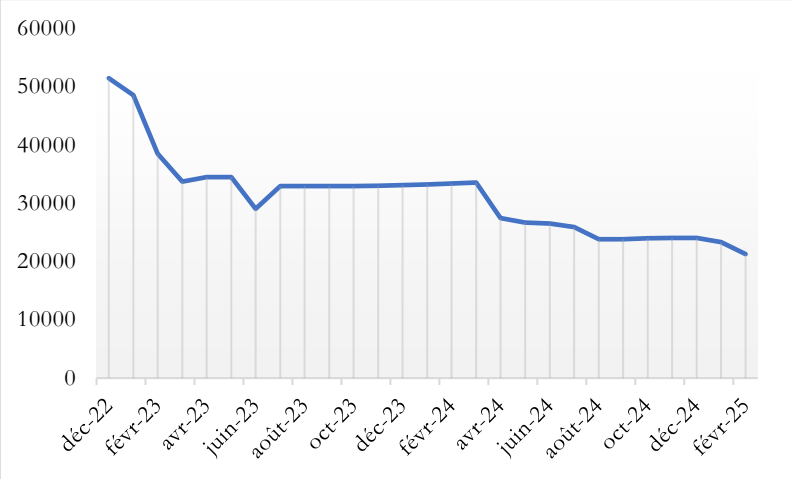
2. From Structural Shift to Speculative Stress: An Archaeology of Cobalt Price Dynamics in Three Acts

The recent evolution of cobalt prices cannot be understood through a purely cyclical lens. Instead, it reflects a succession of deep structural ruptures—economic, technological, and geopolitical—that now shape the trajectory of this critical resource. This section proposes an archaeology of price dynamics observed between December 2022 and March 2025, articulated in three interdependent acts. The first act examines the prolonged price depression in the context of a structural imbalance between global excess supply and a transforming demand. The second explores the DRC's decision to suspend exports and the immediate speculative stress that followed. The third interrogates emerging technological adaptation signals in global demand, suggesting a silent yet decisive inflection point for the future of cobalt. This historical and analytical reconstruction provides the empirical foundation for the intertemporal modeling developed in the next section.

[5] An alternative to import quotas is the Voluntary Export Restraint (VER), a term widely used in the technical and legal vocabulary of international economics. While journalists and the public often refer to these as "export quotas," the terminology employed within the framework of the World Trade Organization (WTO) refers instead to expressions such as "voluntary export restraint arrangements," "export self-restraint," or "orderly marketing arrangements" (Krugman *et al.*, 2012). These mechanisms are typically negotiated between the exporting and importing countries, allowing the former to limit its own export volumes to preempt the imposition of more restrictive measures by the latter.

A longitudinal analysis of cobalt prices from December 2022 to February 2025 reveals a pronounced downward trajectory, indicative of a persistent mismatch between expanding supply and shifting global demand (Figure 1).

Figure 1. Monthly Average Cobalt Price (USD/t)



Source: INSEE; London Metal Exchange (LME)

As shown in Table 1, the average monthly cobalt price dropped from USD 51,481 per metric ton in December 2022 to USD 21,282 in February 2025, a cumulative decline of 58.7% over fifteen months. This sustained drop is not merely a cyclical fluctuation, but a structural distortion of the market, primarily driven by the surge in globally traded volumes. This excess supply is fueled by poorly regulated artisanal mining in the DRC and the rapid emergence of new producers such as Indonesia, whose HPAL (High Pressure Acid Leaching) projects have significantly increased cobalt hydroxide output. The unregulated nature of this supply shock has progressively saturated the market, exerting constant downward pressure on prices.

Table 1. Monthly Average Cobalt Price (USD/t)

Month	Price (USD/t)
Jun-23	51 481
Dec-23	48 556
Jan-25	29 083
Feb-25	33 110
Jun-23	23 346
Dec-23	21 282

Source: INSEE ; London Metal Exchange (LME)

In parallel, global demand underwent a strategic shift. Rising geopolitical uncertainty (including the war in Ukraine, Sino-Western trade tensions, and the aftershocks of Trump-era trade policies[6]), combined with environmental concerns and evolving energy storage technologies, has altered the demand structure. Electric vehicle (EV) manufacturers—especially in China—have accelerated the adoption of lithium-iron-

[6] The election of Donald Trump as President of the United States marked a turning point in global financial markets and international relations. His governing style—characterized by unpredictability, confrontational rhetoric, and unilateral decision-making—introduced heightened levels of geopolitical uncertainty.

Key developments under his administration, such as trade wars, protectionist policies, and unexpected moves on the global stage, significantly increased market unpredictability and contributed to elevated financial volatility. These tensions amplified geopolitical risks and have been associated with commodity price instability and fluctuating international investment patterns. This environment of uncertainty has influenced the structure of global demand across several strategic sectors, including critical minerals. The heightened sensitivity to supply-chain reliability in this context may have reinforced the shift toward technological alternatives and reshaped long-term resource dependencies.

phosphate (LFP) batteries, which require no cobalt, as a means of reducing exposure to volatile and politically sensitive supply chains (Walvekar *et al.*, 2022; Chen *et al.*, 2024). This technological pivot has further constrained the capacity to absorb surplus cobalt, intensifying downward pressure on prices (Hu *et al.*, 2024; George *et al.*, 2024).

Hence, the fall in cobalt prices cannot be dissociated from this global restructuring of the value chain. Despite its production dominance, the DRC remains structurally vulnerable in the absence of effective regulatory instruments. This fragility is one of the key rationales behind the strategic export suspension implemented in February 2025, analyzed in more detail in subsequent sections.

Beyond the observed long-term price decline, data also reveal structurally high market volatility. As shown in Table 2, monthly price fluctuations averaged 14.87%, a critical threshold for a resource so strategic and sensitive to global industrial trends. Notable fluctuations occurred in April 2024 (-18.15%) and June 2023 (-15.67%). This volatility, largely stemming from the absence of robust stabilization mechanisms, severely undermines revenue predictability for exporting states like the DRC and weakens financial stability for private operators. It hampers the conclusion of medium-term supply contracts and exposes firms to liquidity risks and persistent margin uncertainty.

Table 2. Monthly Cobalt Price Volatility (%)

Month	Monthly Variation (%)
Jan-23	-5,69%
Mar-23	-12,32%
Jun-23	-15,67%
Apr-24	-18,15%
Feb-25	-8,89%

Source: Author's calculation based on LME data

Moreover, such price instability fuels speculative behavior in financial markets, exacerbating the gap between real economic fundamentals and investor expectations. It creates an information asymmetry detrimental to primary producers, who rely on volatile fiscal revenues often unbuffered by macroeconomic stabilizers. At the national level, this volatility heightens the DRC's exposure to exogenous shocks, especially those originating from Chinese demand or technological adjustments in the automotive sector. In the absence of effective policy instruments—such as Voluntary Export Restraints (VERs), export tariffs, or intergovernmental coordination agreements, this volatility could compromise the DRC's economic sovereignty and derail its structural transformation agenda. The government's decision in February 2025 must thus be read as an attempt to disrupt this destabilizing spiral.

Against this backdrop of acute volatility and prolonged imbalance, the DRC enacted a precedent-setting policy on February 22, 2025: a four-month suspension of cobalt exports. The dual objective was to induce a global supply contraction that would trigger a price rebound while reasserting sovereign control over a resource deemed critical to the energy transition. The effects were nearly immediate: as shown in Table 3, the average cobalt price surged from USD 21,282/t in February to USD 35,110/t in March 2025, marking a spectacular 64.96% monthly increase. This sharp reaction underscores the DRC's strategic centrality in the global cobalt market and the extreme sensitivity of supply chains to disruptions from the country.

Table 3. Immediate Impact of Export Suspension on Cobalt Prices

Month	Price (USD/t)	Monthly Change (%)
Feb-25	21 282	—
Mar-25	35 110	**64,9%**

Source: Author's calculation based on LME data

While this price spike temporarily improved producer margins and strengthened the DRC's negotiating position, it also introduced systemic risks. Absent a predictable and coordinated regulatory framework, such volatility could trigger downstream market distortions—particularly among refiners, battery manufacturers,

and automotive OEMs. If prolonged or recurrent, this speculative surge might accelerate the shift to cobalt-free technologies, especially LFP batteries. Therefore, while the export suspension proved effective as a short-term lever, it underscores the urgent need for a structural strategy—through phased regulatory instruments (VERs, export tariffs, bilateral partnerships)—to safeguard the DRC's long-term leadership in the global cobalt value chain.

Importantly, the price surge was not confined to LME-listed refined cobalt. Cobalt hydroxide, a critical intermediate used in lithium-ion battery production, also experienced a dramatic revaluation. As shown in Table 4, its average price rose from USD 12,566/t on February 21, 2025, to USD 23,149/t one month later—an 84% increase. This broad-based spike reflects the cross-cutting nature of the supply shock, impacting not only internationally traded finished products but also essential inputs for Asian refiners. It highlights growing vulnerability among Asian markets, which rely heavily on Congolese exports and must now anticipate logistical disruptions to secure their transformation chains. The spike also reflects precautionary dynamics rather than immediate scarcity. Anticipation of prolonged supply tightening triggered a market panic, with Asian refiners scrambling to hedge against extended constraints or the formal introduction of export quotas and duties. This speculative tension illustrates the structural leverage retained by the DRC—even within intermediate segments of the value chain. However, if uncoordinated with major processing hubs, such leverage may eventually trigger substitution strategies by Asian actors seeking to diversify supply.

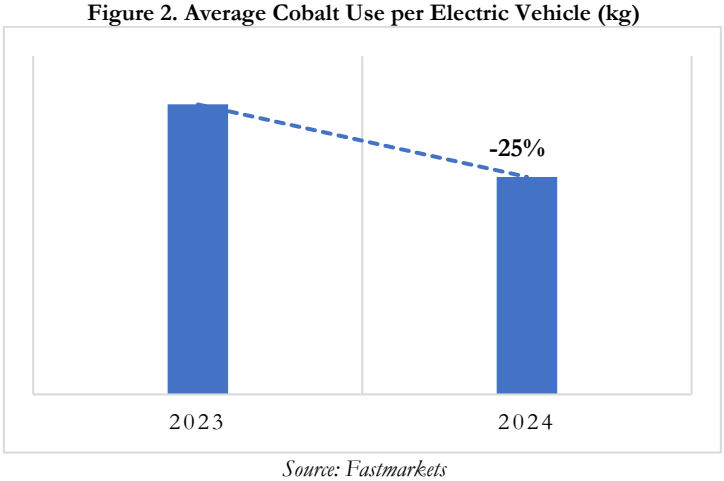
Table 4. Impact on Cobalt Hydroxide Prices

Date	Price (USD/t)	Change (%)
February 21, 2025	12 566	—
March 21, 2025	23 149	84%

Source: Fastmarkets, Cobalt standard grade; Alexander Cook and Sahil Shaw (2025)

Finally, a structural warning signal emerges from the demand side. The average cobalt content per electric vehicle fell by 25% between 2023 and 2024—marking a major technological inflection (Figure 2). This evolution is far from anecdotal. It reflects the rapid ascent of LFP batteries, which offer decisive advantages: lower production costs, greater thermal stability, and complete exclusion of cobalt (Shen et al., 2024). Once confined to the Chinese market, this technology is now gaining ground in Western markets, including Europe and North America, as automakers seek to reduce their reliance on critical materials from geopolitically unstable regions.

Figure 2. Average Cobalt Use per Electric Vehicle (kg)



Source: Fastmarkets

This gives rise to a strategic paradox: while the February 2025 export suspension triggered an immediate price spike, it may, over the medium to long term, catalyze substitution dynamics. By making cobalt more expensive and less accessible, the measure mechanically incentivizes firms to accelerate investment in alternative technologies and to rethink global supply chains. This dual movement could weaken the DRC's long-term strategic position in the international cobalt market, especially if supply regulation remains erratic

or unilateral. Therefore, the DRC must urgently transition from a "shock logic" to a coordinated governance logic—combining calibrated export regulation (via VERs or export duties), incentives for local value addition, and deeper integration into regional and global value chains.

In the face of this complex equation, it becomes essential to move beyond short-term interpretations and rigorously model the intertemporal trade-offs confronting the DRC. The central question, therefore, is the following: do the expected long-term benefits justify the immediate economic losses induced by the suspension? To address this question, the next section employs a theoretical framework based on Hamiltonian formalism, which enables the aggregation over time of the various costs (fiscal, private—particularly for mining operators—and macroeconomic) and potential benefits (price increases, industrial upgrading, and market power). This analytical approach provides a dynamic reading of the Congolese strategy, bridging economic rigor with political realism.

3. Modeling Mineral Sovereignty: A Hamiltonian Perspective on the Congolese Strategy

Considering the empirical shifts observed in cobalt prices in the months preceding and following the DRC's decision to suspend exports, it becomes imperative to move beyond a purely short-term reading of the facts. The policy enacted by Kinshasa cannot be interpreted merely as a reactive response to market signals; rather, it falls within a deeper logic of intertemporal optimization, in which policymakers strategically arbitrate between immediate, incurred costs and anticipated future gains (Martínez-Martínez, 2014; Bakker & Knoben, 2015; Medina-López *et al.*, 2023). To evaluate the economic sustainability of this strategy, this section adopts a rigorous theoretical framework based on the Hamiltonian formalism (Vinogradov & Krasil'shchik, 1975; Cass & Shell, 1976; Wulwick, 2002; Velupillai & Zambelli, 2015), which enables the aggregation of economic flows over a defined time horizon and the projection of their net present value.

However, the robustness of such a strategy hinge on a set of structural conditions that are critical to its viability. First, the management of the political discount rate directly influences the State's ability to arbitrate between budgetary urgency and strategic foresight. Second, the timing of policy implementation must align with the intertemporal discounting horizon to avoid erosion of future gains. Third, an adaptive and inclusive governance framework—rooted in structured dialogue with private stakeholders—determines the legitimacy and effectiveness of the deployed instruments. Finally, bilateral geoeconomic coordination, particularly with Indonesia, could act as a systemic multiplier of market stability and bargaining power. A comprehensive analysis of these levers therefore constitutes the analytical foundation of a sustainable and sovereign mining strategy for the DRC.

The suspension of cobalt exports must not be understood solely through the lens of immediate economic loss or short-term market reaction. Instead, it reflects what can be conceptualized as an intertemporal optimization strategy, whereby public decision-makers deliberately accept an initial cost in the hope of generating larger deferred gains. To model such risk-taking rationally over time, one may employ a more advanced economic formalism: the Hamiltonian model.

3.1. Intertemporal Problem Formalization: Arbitrating Between Present Losses and Future Rents

The government's strategy can be formalized within the canonical framework of the Hamiltonian model, as defined below:

$$H = \int_{t}^{T} [B(t) - C(t)]\, e^{-\rho t} dt$$

This formalism enables the calculation of the net present value H of the national strategy by aggregating all projected costs and benefits over the time horizon $[0, T]$, with each flow weighted by the temporal preference factor $e^{-\rho t}$.

Within the context of the DRC's (DRC) export suspension policy, the structure of costs and benefits under this intertemporal Hamiltonian model can be synthesized as follows:

- $C(t)$ **– Immediate Costs:** These encompass all economic losses directly induced by the suspension, including:
  - ❖ Fiscal revenue losses resulting from the temporary export ban;
  - ❖ A slowdown in GDP due to reduced activity across the mining value chain;
  - ❖ A depletion of foreign currency reserves due to reduced export earnings, which may put downward pressure on the Congolese franc (CDF) and intensify inflationary tensions;
  - ❖ Private-sector costs borne by mining operators, including inventory immobilization, contract breaches, and slowed investment cycles.
- $B(t)$ **– Projected Benefits**: These represent the anticipated gains that materialize only over time:
  - ❖ A rebound in global cobalt prices, leading to increased revenue potential upon the resumption of exports;
  - ❖ Enhanced bargaining power for the DRC as a price-maker, through the deployment of Voluntary Export Restraints (VERs) or export tariffs;
  - ❖ Promotion of domestic value addition, through incentives and pressures placed on firms to develop in-country processing capacities (refining, components, batteries) ;
  - ❖ Geostrategic repositioning, particularly via a prospective DRC–Indonesia alliance to coordinate global supply.
- ρ **– The Discount Rate** : This critical parameter reflects the temporal preferences of public decision-makers:
  - ❖ A high discount rate ($\rho \gg 0$) denotes a strong preference for immediate gains, thus heavily discounting future benefits—indicative of a short-term strategy.
  - ❖ A low discount rate ($\rho \approx 0$) indicates a patient strategic orientation, whereby the government is willing to absorb short-term costs in pursuit of larger long-term gains—typical of long-term policy design.

3.2. Short-Term Dynamics: An Initial Deficit Trajectory

In the immediate aftermath of the cobalt export suspension—defined over the interval $t = 0 \rightarrow t_1$, the Congolese economy enters a state of disequilibrium, characterized by a predominance of costs over benefits. Formally:

$$C(t) > B(t) \rightarrow H(t) < 0$$

In other words, the short-term Hamiltonian value becomes negative, reflecting a situation in which immediate economic losses substantially outweigh the still-hypothetical potential gains.

Decomposition of Short-Term Costs

Immediate costs can be disaggregated into three primary components:

$$C(t) = C_{fiscal} + C_{private} + C_{macro}$$

- C_{fiscal} : **Fiscal Losses**. This represents the direct reduction in public revenues. In the absence of export activity, the government forfeits mining royalties and related tax inflows. Assuming a 40% contraction in cobalt exports, fiscal revenues may fall by an estimated 12% to 15%. This decline imposes a direct strain on the national budget, which is already under pressure from growing social demands and security-related expenditures due to ongoing conflict.
- $C_{private}$: **Private Sector Costs**. This component includes the economic burden borne by mining firms, such as:
    - ❖ Inventory immobilization due to the inability to export;
    - ❖ Liquidity constraints, as fixed costs persist while revenue flows are delayed;
    - ❖ Contractual penalties resulting from missed delivery deadlines;
    - ❖ Partial or complete shutdowns of production operations.

These effects are particularly acute for small and medium-sized mining enterprises, whose resilience to exogenous shocks is limited. For mid-sized projects, monthly losses may amount to several million USD.

- C_{macro} : **Macroeconomic Effects**. These encompass the broader spillover impacts on the national economy. Given that the mining sector accounts for approximately 50% of GDP and over 80% of foreign exchange revenues, a contraction in mining activity triggers a growth deceleration. Immediate projections suggest a 2–3 percentage point reduction from the initially forecasted 5.1% growth rate for 2025, driven by:
    - ❖ A downturn in private investment;
    - ❖ Weakened domestic demand ;
    - ❖ Heightened pressure on the exchange rate due to declining foreign currency reserves.

Taken together, in this initial phase, the Hamiltonian value can be expressed as:

$$H(t) = (B(t) - C(t)) \cdot e^{-\rho t}$$

This yields a negative outcome, as $C(t)$ remains high while $B(t)$ is marginal or even null reflecting the fact that expected benefits do not materialize immediately.

The temporal discount factor $e^{-\rho t}$ amplifies this imbalance by reducing the present value of future gains. The higher the discount rate ρ (i.e., a strong preference for short-term returns), the more penalizing the current losses become in the intertemporal trade-off.

The cost of suspension is certain and immediate, whereas the benefits remain uncertain and delayed. It is precisely this temporal asymmetry that renders the strategy risky—yet potentially rewarding, if well executed. As such, the economic diagnosis underscores the necessity of a credible exit strategy to prevent a decoupling of market expectations and an erosion of the country's strategic legitimacy.

3.3. Medium-Term Outlook: A Potential Shift Toward a Positive Hamiltonian Balance

Provided that a rigorous structural transformation policy is effectively implemented, the intertemporal trajectory modeled by the Hamiltonian framework may pivot toward a favorable outcome. Following an initial adjustment period—estimated between six to twelve months and corresponding to the post-suspension phase—the national economy could embark on a path of gradual recovery. This, however, is contingent upon the deployment of complementary measures beyond the unilateral suspension of exports, including local industrialization initiatives, institutional reforms, and the establishment of strategic partnerships.

- **Progressive Growth of $B(t)$**

Assuming the government actively promotes the establishment of local cobalt processing units—through targeted fiscal incentives and robust regulatory mechanisms such as digital traceability, then the benefit function $B(t)$, would begin to exhibit a growth trajectory. Mathematically, this condition is expressed as:

$$\frac{dB(t)}{dt} > \frac{dC(t)}{dt}$$

This inequality signifies a scenario in which the growth rate of expected benefits exceeds that of residual costs. From an economic standpoint, such a configuration would materialize through:

- ❖ An increase in local profit margins, driven by the retention of value-added within the national territory;
- ❖ A delayed but significant improvement in fiscal revenues, notably through value-added tax (VAT) on processed products and corporate income tax from newly created firms;
- ❖ Positive labor market dynamics, especially for skilled employment, thereby generating multiplier effects on domestic demand and consumption.

- **Gradual Recovery Toward a Positive Hamiltonian Value**

Once the cumulative future benefits surpass the initial costs, the net value of the strategy—captured by the Hamiltonian formulation,

$$H(t) = \int_t^T [B(t) - C(t)]\, e^{-\rho t} dt$$

—becomes potentially positive. This turning point signals medium-term economic viability, suggesting that the strategy is beginning to yield net positive returns. However, the realization of such a favorable scenario remains contingent upon two critical parameters:

- ❖ The speed of reform implementation: A sluggish rollout of accompanying mechanisms delays the growth of $B(t)$, thereby intensifying the discounting effect applied to future gains through the temporal preference factor $e^{-\rho t}$;
- ❖ The discount rate ρ : The higher the policymaker's preference for immediate gains, the more politically challenging it becomes to justify a strategy whose payoffs are deferred. A high discount rate diminishes the present value of future benefits, thereby undermining the perceived legitimacy of the policy in the short run.

3.4. Integrating Trade Policy Instruments: Modulating Without Disrupting

Considering the short-term fiscal imbalances and the inherent uncertainties surrounding the medium-term recovery trajectory, it is essential for the Democratic Republic of Congo (DRC) to adopt a strategy of gradual adjustment. Rather than pursuing a prolonged and complete suspension of cobalt exports, the implementation of adjustable Voluntary Export Restraints (VERs) and/or differentiated export duties emerge as a more economically rational intermediate policy (Espa, 2015). Such an approach would maintain a degree of artificial scarcity in international markets, thereby supporting prices, while simultaneously restoring partial financial flows essential to both state budget equilibrium and the liquidity needs of mining operators (Hoekman & Nicita, 2018).

- **Mathematical Formalization of Commercial Modulation**

From a formal standpoint, these trade policy tools can be incorporated into the benefit function of the Hamiltonian model through the following extended equation:

$$B_{policy}(t) = B(t) + \theta_1 \cdot VER\ (t) + \theta_2 \cdot Duty(t)$$

Where:

- $B(t)$ denotes the endogenous benefit derived from local value addition, industrial upgrading, and market stabilization;
- $VER\ (t)$ represents the volume of cobalt authorized for export at time t ;
- $Duty\ (t)$ denotes the export tariff rate applied at time t ;
- $\theta_1\ et\ \theta_2$ are transmission coefficients capturing the marginal impact of each instrument on the aggregate benefit function.

This formulation enables simulation of the combined effects of these instruments on the intertemporal balance $H(t)$, orienting it toward positive values while preserving macro-commercial stability.

- **Voluntary Export Restraints: Toward Controlled and Regulated Scarcity**

VERs constitute a mechanism of controlled scarcity, distinguished from outright export bans by their flexibility. By allowing a limited but predictable flow of cobalt to international markets, VERs:

- Prevent excessive inventory accumulation at the producer level;
- Ensure the minimum fulfillment of contractual obligations, thereby reducing regulatory and reputational risks;
- Support international price levels without disrupting continuity in trade relations.

As such, VERs contribute simultaneously to revenue stability for operators and predictability for commercial partners, aligning national sovereignty goals with global market integration.

- **Export Duties: Reclaiming the Public Rent**

Dynamically calibrated export duties serve as a fiscal stabilization instrument that avoids a reversion to a raw extractive model. Applied proportionally to export volumes or adjusted in relation to global price levels, these levies:

- Provide short-term fiscal space;

- ❖ Encourage producers to redirect a portion of their operations toward domestic processing, which is less tax-burdened;
- ❖ Enhance state capture of mining rents within a redistributive sovereignty framework.

In essence, export duties function as a dual tool for fiscal and industrial regulation, strengthening the $B(t)$ function within the Hamiltonian intertemporal dynamic.

- **Gradualism and Shared Governance**

The success of this integrated commercial strategy rests on two major institutional conditions:

1. **Gradual implementation**: A phased introduction of VERs and/or export duties mitigates disruption risks for mining operators. A calibrated transitional period, paired with administrative support, is essential to ensure reform acceptability and operational smoothness.
2. **Public-private dialogue**: Building a sectoral consensus is critical. Close consultation between the state, the Chamber of Mines, exporting companies, refiners, and international partners should allow for the co-design of tariff schedules, authorized volumes, and monitoring mechanisms. This would help prevent evasion, circumvention, or disinvestment behaviors.

Ultimately, these instruments represent hybrid tools situated at the intersection of state regulation and market functioning. If properly designed and implemented within an inclusive governance framework, they offer the potential to increase the net present value H in the Hamiltonian model without significantly inflating the cost function $C(t)$. As such, they can accelerate the DRC's transition toward predictive, sovereign, and strategic resource management, while fostering a more rational and attractive investment climate.

3.5. Toward a Bilateral Regulatory Architecture: The DRC–Indonesia Bet on a Cobalt OPEC?

Ultimately, the strategic sustainability of the Democratic Republic of Congo's (DRC) suspension of cobalt exports cannot rest solely on unilateral instruments such as Voluntary Export Restraints (VERs) or export tariffs. Rather, it could be significantly enhanced through a bilateral cooperation framework, currently under negotiation with Indonesia, the world's second-largest cobalt producer. This initiative holds the potential to establish a coordinated governance structure for the global cobalt supply—an embryonic "Cobalt OPEC", mirroring cooperative arrangements in the petroleum sector.

- **A Dominant Producers' Alliance: 88% of Global Supply**

As of 2024, the DRC and Indonesia together accounted for approximately 88% of global cobalt production[7]. While the DRC holds the world's largest high-grade reserves, Indonesia is rapidly scaling up its output through High-Pressure Acid Leaching (HPAL) projects, which produce Mixed Hydroxide Precipitate (MHP), a critical precursor in battery supply chains (ChuanYu, 2024; Michel, 2024). A coordinated strategy between these two producers would enable the deployment of joint regulatory instruments, synchronized VERs, price floors, and differentiated export controls—laying the groundwork for an oligopolistic governance model of the cobalt market.

- **Market Stabilization and Volatility Reduction**

From an economic standpoint, such cooperation would contribute to smoothing excessive price volatility, a key impediment to industrial planning for downstream users and to the fiscal predictability of national

[7] *Fastmarkets*

mining policies. Within a Hamiltonian intertemporal optimization framework, this stabilizing effect can be formally represented as:

$$H_{Coop} = H + \gamma \cdot Stability_{Market}$$

Where, H_{Coop} denotes the net intertemporal value under bilateral cooperation, and γ is a stabilizing amplification coefficient. The greater the effectiveness of coordination, the higher the γ, reducing uncertainty, attracting investment, and enhancing the joint bargaining power of producing countries vis-à-vis global refining centers.

- **From Price-Taker to Price-Maker: A Paradigm Shift**

Historically, the DRC has operated as a price-taker, passively subjected to price formation by downstream actors in the value chain. A bilateral alliance with Indonesia represents a structural opportunity to transition into a price-maker role, enabling proactive influence over global supply dynamics. However, such a shift requires:

- ❖ Harmonization of exchange rate regimes, tax systems, and mining policies;
- ❖ Operational transparency regarding production capacities;
- ❖ Active economic diplomacy with key refining centers (China, the European Union, and the United States).

Moreover, the implementation of joint price floors or VER frameworks would provide both countries with anti-cyclical capabilities, allowing them to manage supply gluts and price collapses proactively.

- **A Win-Win Cooperation Under Political Constraints**

Despite its strategic appeal, the political feasibility of this bilateral alliance hinges on several variables: institutional stability in both countries, alignment of economic agendas, and resistance from global industrial stakeholders, who may attempt to undermine or bypass the initiative through fragmentation or technological substitution strategies. Furthermore, excessive reliance on such coordination mechanisms may accelerate the shift toward cobalt-free battery technologies, such as Lithium Iron Phosphate (LFP), thereby eroding the long-term bargaining leverage of cobalt-producing nations.

3.6. Toward a Bilateral Regulatory Architecture: Strategic Calibration, Polycentric Governance, and Multilevel Coordination as Conditions for Success

The Hamiltonian modeling framework reveals that the net present value of the DRC's export suspension strategy critically hinges on the alignment of a coherent set of structural and institutional variables. The intertemporal performance of this policy depends on four fundamental levers whose proper configuration is the sine qua non condition for transitioning from a logic of short-term disruption to one of sustainable sovereignty. These levers are: (i) *the calibration of the political discount rate*, (ii) *the timing of reform implementation*, (iii) *the quality of contractual multi-stakeholder governance*, and (iv) *the intensity of bilateral geoeconomic coordination*. Each represents a critical variable in optimizing the Hamiltonian value function of the Congolese strategy.

a. Political Discount Rate: Balancing Budgetary Urgency with Strategic Vision

Within the Hamiltonian framework, the discount rate parameter ρ reflects the public decision-maker's time preference. A high value $(\rho \gg 0)$ signals strategic impatience, in which future gains are heavily discounted, rendering any deferred action politically and fiscally costly. Conversely, a low discount rate $(\rho \approx 0)$ indicates a long-term strategic orientation that favors present sacrifice for future returns.

Recommendation: To anchor its mining policy in a sustainable trajectory, the DRC should adopt a logic of strategic patience by maintaining a low discount rate. This implies establishing macroeconomic stabilizers—such as a sovereign wealth fund, notably the Mining Fund (FOMIN) for Future Generations[8], or multilateral budgetary support mechanisms—to absorb short-term fiscal losses and preserve fiscal sustainability during the transition phase (Ntungila & Pinshi, 2019).

b. Reform Timing: Aligning Real Impact with the Discounting Window

The temporal dimension of reform implementation is a decisive factor in intertemporal optimization (Reuben, 2004). The slower the deployment of supportive measures (local refining, logistical traceability, incentive-based regulation and taxation), the flatter the temporal derivative of the benefit function $B(t)$. Given the presence of the discount factor $e^{-\rho t}$, any delay leads to a substantial reduction in the present value of future gains within the Hamiltonian equation.

Recommendation: To preserve the intertemporal integrity of the model, the DRC must minimize administrative inertia by enacting a binding regulatory timeline, swiftly operationalize local processing units, and accelerate the integration of traceability technologies to ensure the effective growth of B(t) within the relevant decision window.

c. Adaptive Governance: Toward a Negotiated Public–Private Contract

The success of any regulatory policy depends heavily on its acceptability (North, 1990; Rodrik, 2008; Baldwin *et al.*, 2011; Stigler, 2021). A purely unilateral approach—imposing VERs or export tariffs without stakeholder consultation—risks generating adverse effects: circumvention behavior, disinvestment, or the disorganization of supply chains. As a welfare-aggregating function, the Hamiltonian model implicitly incorporates the behavioral feedback of economic agents.

Recommendation: A contractual governance framework is essential, involving the state, the Chamber of Mines, refiners, and relevant national institutions. Establishing a National Cobalt Governance Committee—mandated to negotiate VER parameters and export tariff structures—would enable an adaptive policy calibration that maintains the coherence of the benefit function and avoids disruptive discontinuities.

d. Strategic RDC–Indonesia Cooperation: Stabilizing the Model through Positive Externalities

The geoeconomic lever of bilateral cooperation offers systemic stabilization potential (Sachs & Warner, 1995; Keohane, 1977). Within the Hamiltonian framework, such cooperation can be modeled as a positive externality captured by an amplification factor γ, enhancing the overall robustness of the strategy. The resulting expression becomes:

$$H_{Coop} = H + \gamma \cdot Stability_{Market}$$

Where, H_{Coop} denotes the net intertemporal value under cooperation, and γ reflects the marginal sensitivity of the strategy to induce stability effects.

Recommendation: The formalization of a DRC–Indonesia cooperation agreement via a Memorandum of Understanding is strongly advised. This should incorporate coordination mechanisms for VER implementation, price floors, and trade flow predictability. The establishment of a bilateral Data Hub,

[8] *Law No. 007/2002 of July 11, 2002, on the Mining Code, as amended and supplemented by Law No. 18/001 of March 9, 2018*, provides for the creation of a Mining Fund (FOMIN) for Future Generations, financed by 10% of the mining royalty (*Article 242*). While the fund represents a strategic initiative for economic stability and resilience, its implementation has been hampered by issues of transparency and oversight. As highlighted by Ntungila and Pinshi (2019), despite its potential, the fund's governance and management strategy remain opaque, calling for a clear institutional definition and transparent governance framework to ensure its long-term effectiveness and impact.

coupled with a joint demand forecasting committee, could form the technical foundation for a future international cobalt producers' organization.

Far from being a purely theoretical exercise, the application of the Hamiltonian model to the cobalt export suspension strategy provides a rigorous framework for rationalizing intertemporal trade-offs. It integrates short-term constraints with long-term structural potentials. Success hinges on the careful orchestration of time preferences, reform sequencing, inclusive governance mechanisms, and strategic alliances. Under this lens, Congolese cobalt transcends its status as a mere extractive rent and emerges as a strategic variable of economic policy, warranting advanced analytical tools and decisions grounded in dynamic equilibrium reasoning.

4. Conclusion

The export suspension of cobalt enacted by the Democratic Republic of Congo (DRC) in February 2025 represents a historic turning point in the governance of its strategic mineral resources. Far from being a mere reactive measure in response to falling prices, this decision reflects a deliberate strategy to recalibrate the balance of power between producing countries and global value chain transforming a volatile mineral rent into a lever of economic sovereignty.

Empirical analysis of cobalt price dynamics, the emergence of speculative stress, and ongoing technological shifts in global demand—particularly the rise of lithium iron phosphate (LFP) batteries—confirm the increasing complexity of the cobalt geoeconomic environment. In such a turbulent context, the DRC has attempted to assert influence through a supply-side shock, aiming to reverse asymmetric dependence. However, the long-term effectiveness of such a strategy hinge less on its capacity to disrupt, and more on its ability to embed itself within a robust framework of intertemporal governance.

This is precisely the analytical value of the Hamiltonian framework: by aggregating immediate costs (fiscal, private, macroeconomic) and projected benefits (price appreciation, local industrialization, market power), it highlights the critical conditions under which a temporary shock may be converted into a strategic gain. The model reveals a fundamental asymmetry between the temporal occurrence of costs (instantaneous) and the realization of benefits (deferred)an imbalance that can only be managed through fine-tuned, strategic policy coordination.

In this regard, four key levers emerge as decisive: the calibration of the political discount rate (reflecting long-term orientation), the speed of structural reform implementation (particularly in industrial upgrading), the establishment of a contractual governance framework with mining operators, and the formation of a structured bilateral cooperation with Indonesia—one that could amplify the net intertemporal value of the Congolese strategy.

Ultimately, this study contends that cobalt should no longer be treated as a commodity to be exported at market price, but rather as a negotiating instrument, a geostrategic asset to be governed, and a catalyst of industrial transformation to be integrated. The DRC's challenge does not lie in its capacity to extract, but in its capacity to govern—across time, across space, and in coordination with a reshaping global economic system. In this light, the Congolese economy stands at the threshold of a potential paradigm shift: from dependence to influence, from volume to power, from rent to sovereignty. Provided, however, that theoretical equations are effectively translated into coherent, adaptive, and inclusive public policies.

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