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Nature loss and external vulnerability in Latin America: insights from Brazil's balance of payments and exchange-rate risks

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Summary

The impact of nature degradation on the balance of payments (BoP) and exchange-rate dynamics is an underexplored but critical channel for understanding macroeconomic risks. This is especially true in emerging markets and developing economies (EMDEs) that are reliant on nature-intensive exports. Pressure on ecosystem services such as precipitation regulation, soil fertility and water availability can reduce and destabilise export earnings, raise import costs and dependence, and tighten external financing through higher risk premia.

In Brazil, several important activities for earning foreign exchange are dependent on nature. A significant share of foreign investment in the country is concentrated in sectors with high exposure to ecosystem services. This creates scope for feedback between ecological stress, financing conditions and currency volatility.

Similar vulnerabilities to ecosystem-services dependence and foreign-exchange risks are apparent in EMDEs across Latin America and further afield. Moderate dependence on ecosystem services is widespread, and very high exposure is concentrated in commodity- and land-intensive economies. The econometric evidence is mixed but points to a link between biocapacity losses and relatively large movements in the exchange rate.

This has major implications for policymakers in EMDEs. The protection of important ecosystem services is critical to a strategy for macroeconomic stability. Efforts to improve BoP resilience will require policymakers to integrate nature-related risks into central bank and supervisory toolkits, fiscal and development planning, cross-government coordination and the international financial architecture.

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The CETEx Discussion Paper Series: Land and Ocean is designed to provide a broader and deeper understanding of environmental risks by introducing economic and financial policymakers to ecosystem degradation issues such as deforestation, pollution and biodiversity loss on land and in the oceans. The series aims to support financial and economic policymakers as they contend with and make considerations for these environmental degradation issues, in addition to climate change. The papers have been written and peer-reviewed by leading experts from academia, think tanks and central banks and are based on cutting-edge research.

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1. Introduction

Emerging markets and developing economies (EMDEs) face a recurring macroeconomic dilemma in how to maintain currency credibility and access to external finance while pursuing structural change and inclusive growth. For many, that challenge is sharpened by two structural features: high exposure to global financial cycles, and export-driven growth models concentrated in ecosystem-dependent tradables. In this context, nature degradation such as biodiversity decline, soil erosion, water stress, deforestation and the erosion of ecosystem services can become a macroeconomically important source of external vulnerability.

The balance of payments (BoP) – the economic transactions between a country's residents (individuals, businesses, and government) and the rest of the world – is a key transmission channel for this vulnerability. When export revenues fall, import needs rise or external financing conditions tighten, adjustment can occur through reserve losses, currency depreciation, higher domestic interest rates or contractionary macroeconomic policy. Nature degradation can intensify this adjustment by simultaneously hitting exports, imports and financing. It does so by lowering export volumes and reliability, raising exposure to food and energy shocks, and increasing risk premia through disruption, compliance and transition concerns.

Brazil makes for an informative case study of these effects. A large share of its export receipts comes from sectors that depend on ecosystem services, and its exchange rate and external financing conditions can tighten quickly when shocks raise uncertainty and risk premia. This provides a clear setting in which to trace how nature degradation can translate into BoP stress.

"Nature degradation can become a macroeconomically important source of external vulnerability."

The literature on climate and macroeconomics has begun to map adjacent mechanisms. Work on the Global South links climate-related shocks to external balances and exchange-rate outcomes (e.g. Althouse et al., 2020; Bonato et al., 2023; Bortz and Toftum, 2024; Löscher and Kaltenbrunner, 2023, 2025; Svartzman and Althouse, 2020). For instance, Bortz and Toftum (2024) show that drought-induced declines in agricultural activity reduced foreign exchange (FX) reserves in Argentina. Löscher and Kaltenbrunner (2023, 2025) argue that climate pressures increase exchange-rate volatility through weaker commodity terms of trade and climate-related capital flight, while Cheema-Fox et al. (2022) find that physical climate-risk events are associated with relatively large depreciations in non-G10 currencies. In parallel, some research links commodity booms to currency appreciation (Chen and Rogoff, 2003; Cashin, Céspedes and Sahay, 2004) and emphasises the role of financial reversals and overshooting in this process (Drechsel and Tenreyro, 2018; Fernández, González and Rodríguez, 2018; Sockin and Xiong, 2015; Nalin and Yajima, 2021; Van Huellen and Palazzi, 2023).

Consistent with this, Bonizzi et al. (2025) document strong asymmetries in low- and middle-income countries: busts raise depreciation tail risk on impact,[1] while booms lead to lower tail risk in the short term but higher tail risk in the longer term, effects that increase with the share of local bonds held by non-bank financial institutions (NBFIs). Methodologically, exchange-rate research has moved away from binary 'crisis' models and towards tail-risk approaches (quantile regressions and growth-at-risk). These approaches focus on the extreme ends of the distribution

[1] 'Tail risk' refers to the probability of unusually large exchange-rate depreciations.

and are better suited to rare, nonlinear adjustment episodes: infrequent but potentially abrupt and disproportionate exchange-rate corrections (Adrian, Boyarchenko and Giannone, 2019; Gächter, Geiger and Hasler, 2023; Eguren-Martin and Sokol, 2022).

Yet few studies have explored the implications of nature degradation for BoP and exchange-rate dynamics. This is important because ecosystem services underpin production and resilience: around half of global GDP is estimated to depend on functioning ecosystems (World Economic Forum, 2023). Moreover, ecosystems are rapidly degrading: land-use change has generated large estimated losses in ecosystem-service value (Costanza et al., 2014), and global assessments document intensifying pressures on land, biodiversity and water systems (IPBES, 2019; UNCCD, 2022, 2024; WWF, 2024). For many EMDEs, ecosystem-dependent agriculture and resource sectors sit at the core of export earnings and external financing capacity.

Much of the current literature has focused on how the economy harms nature or how its degradation can impact financial and macroeconomic stability, with a focus on domestic channels. In contrast, we explore external vulnerabilities. This approach presents an empirical challenge, as ecosystem services are locally contingent and difficult to measure. Moreover, standard modelling can miss hysteresis – persistent effects that continue even after the original disturbance has ended – and cascading effects, whereby an initial disruption propagates through interconnected systems and generates further impacts (Boyd and Banzhaf, 2007; Howarth and Farber, 2002; Kumar et al., 2013; Lenzi et al., 2023; Althouse et al., 2025). Yet these external vulnerabilities have important macroeconomic consequences, even though the most significant effects may arise for larger FX movements and during compound shocks (e.g. nature-related and financial).

"Ecosystem services underpin production and resilience: around half of global GDP is estimated to depend on functioning ecosystems."

This paper focuses on the relationship between nature degradation and increases in BoP stress and FX volatility, synthesising two studies to explore how macroeconomic policymakers can address the resulting challenges. Both studies show the transmission of nature degradation into macroeconomically important effects. The first centres on Brazil and the second takes a broader international view, constructing exposure measures for developing economies and exploring exchange-rate tail risks. The goal is not to claim that nature degradation 'explains' currency movements, but to clarify how it can systematically shape external vulnerability, and to make the case for macroeconomic policy that treats nature conservation and resilience as vital to stability.

2. Methodology

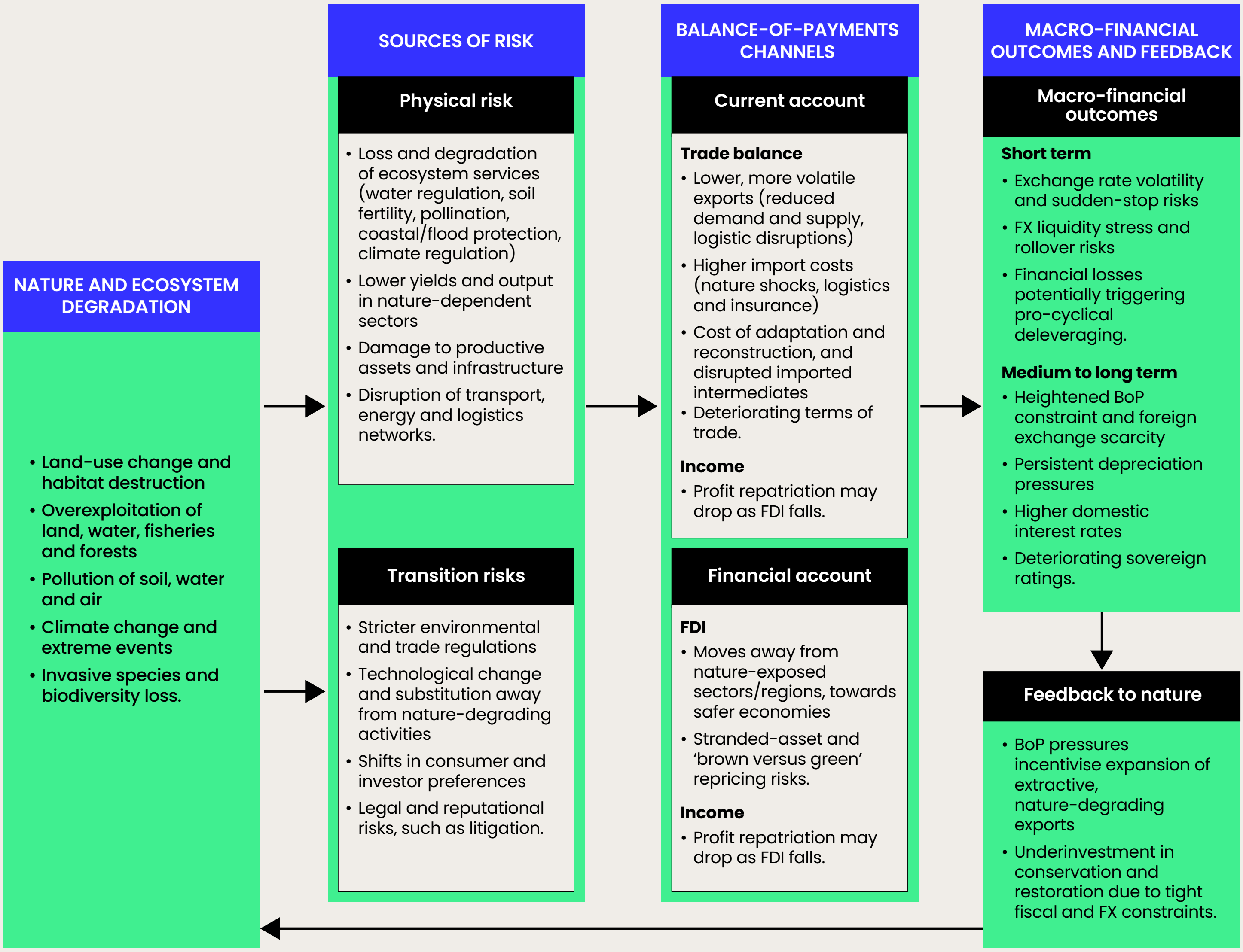
The Brazil-focused study drew on semi-structured interviews with specialists in environmental governance, finance and macroeconomic policy, combined with sectoral mapping that links dependence on ecosystem services to Brazil's external accounts. We used the interviews to shape a theoretical framework and identify the channels through which nature degradation can translate into pressures on exports, imports and financing. The mapping exercise illustrated how those channels aligned with Brazil's trade and foreign direct investment (FDI) structure.

The second study adopted comparable structural exposure metrics for Latin American economies more broadly, by combining ecosystem-service dependence scores with multi-regional input–output tables. It then explored the potential links between ecological conditions and exchange-rate tail risks using panel quantile regressions on quarterly depreciation outcomes.

Linkages between nature degradation and macroeconomics are hard to measure clearly and comparably, as losses of ecosystem services are locally contingent and highly interconnected. We adopted a mixed-methods approach to account for this, given that established metrics can be reductionist and that equilibrium models often miss hysteresis and cascading effects (Althouse et al., 2025; Boyd and Banzhaf, 2007; Howarth and Farber, 2002; Kumar et al., 2013; Lenzi et al., 2023; Lenton et al., 2019).

Figure 2.1 below is the organising framework that guides our approach. It builds on previous research on nature-related economic and financial risks (e.g. Network for Greening the Financial System [NGFS], 2024; Svartzman et al., 2021), distinguishing between physical risks and transition risks.

Figure 2.1. Nature degradation and the balance of payments in nature-dependent economies



Source: Authors' elaboration on NGFS conceptual framework on nature-related financial risks (NGFS, 2022; 2024).

Physical risks include ecosystem-service loss, lower and more volatile output in nature-dependent sectors, damage to assets and infrastructure, and logistics disruption. Transition risks include tighter regulation and associated legal and reputational risk, and shifts in technology and demand away from nature-degrading activities. We mapped the effects of these risks on the current account (goods and services trade, and the income balance) and the financial account (FDI, and portfolio and banking flows).

Nature shocks can weaken and destabilise export revenues, raise import and adaptation-related costs, and tighten external financing through higher risk premia and more volatile capital flows. This translates into exchange-rate volatility and, in more severe cases, sharper BoP adjustment.

Between June and November 2025, we conducted twelve semi-structured interviews with researchers and practitioners in finance, environmental planning and engineering, and public policy. The interviews focused on the ecosystem-service risks most relevant to Brazil, sectoral dependencies and production and logistics mechanisms affected by these risks, and the most plausible external channels (trade, income and financing conditions). The insights we gained from the interviews informed which sectors, flow types and mechanisms we emphasised in the mapping exercise.

The exercise operationalised the framework by measuring ecosystem-service dependence and propagating it through supply chains, before linking exposure to structures relevant to the BoP. We measured sectoral dependence using Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE) ratings across ecosystem services (from null to very high), harmonised with Brazil's input–output sectoring. We converted qualitative ratings into numeric scores to construct direct sectoral dependence profiles, and computed upstream (indirect) exposure using input–output propagation, so that dependence embedded in suppliers was reflected in downstream sectors. We then intersected the resulting direct and upstream exposure measures with sectoral footprints in external accounts – primarily through trade structure and, where the data allowed, investment and financing exposure. This yielded 'BoP exposure maps' showing which current-account and financial-account blocks had the greatest structural sensitivity to the disruption of ecosystem services in Brazil.

The second study applied this approach to a broader international setting, enabling comparisons between countries. We combined ENCORE dependence scores with multi-regional input–output tables from the Global Resource Input–Output Assessment (GLORIA) to compute comparable direct and supply-chain exposure measures across countries. We then estimated panel quantile regressions for quarterly depreciation to assess whether ecological erosion is associated with the tails of exchange-rate volatility, which are more relevant indicators of BoP stress than average exchange-rate movements (see Tables 4.2.1 and 4.2.2 below). We use ecological capacity as a proxy for biocapacity (Lo et al., 2025).[2] We report results for two dependent variables: the magnitude of exchange-rate changes as a measure of volatility (|ΔXR|; see Table 4.2.1); and signed devaluations as a measure of depreciation risk (see Table 4.2.2). Further details on this approach can be found in the Appendix below.

"Nature shocks can weaken and destabilise export revenues, raise import and adaptation-related costs, and tighten external financing."

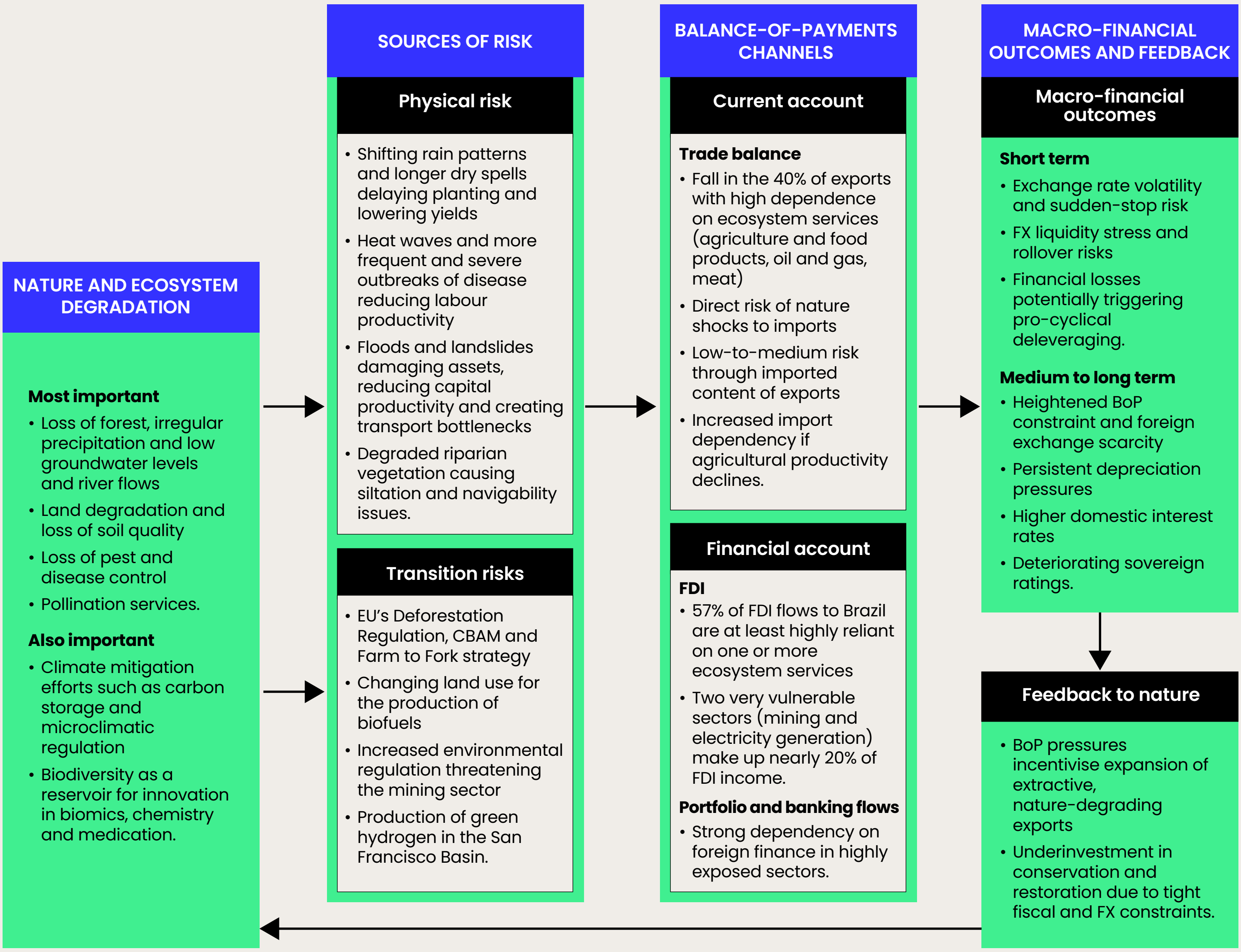
[2] Biocapacity is the biologically productive area available to provide renewable resources (e.g. food, fibre, timber) and to absorb waste (especially CO_2) under prevailing management and extraction technologies. This varies over time with climate conditions and land use (Lo et al., 2025).

3. Brazil: how nature degradation translates into balance-of-payments pressure

As discussed, Brazil provides a useful case study for the linkages between nature degradation and the BoP because its external position is tightly connected to the trade of nature-dependent goods. A large share of the country's export revenues comes from agriculture and other resource-based activities that rely on hydrological regulation, water availability and soil fertility, while parts of its growth model depend on continued access to foreign capital. When nature degradation weakens export capacity or raises perceived risk, the effects can show up as reserve losses, depreciation, higher domestic interest rates and contractionary macroeconomic policy.

Figure 3.1 below applies the general theoretical framework in Figure 2.1 to Brazil. It pinpoints the risk clusters raised in interviews for this study, showing how they are most likely to propagate through the country's trade structure and financing conditions.

Figure 3.1. Nature degradation and the balance of payments in Brazil



Source: Authors' elaboration on the NGFS conceptual framework on nature-related financial risks, using interviews and data analysis (NGFS, 2022; 2024).

The three risk clusters most salient for Brazil's macro-economic position are: forest loss and weaker precipitation regulation; water stress and irregular rainfall (including longer dry spells); and soil degradation and declining fertility. These risks matter not only because they gradually erode productivity, but also because they change rainfall patterns. This leads to greater volatility as it increases the likelihood of droughts, fires and floods, and makes seasonal cycles less reliable – precisely the kinds of disturbance that can destabilise export revenues and restrict access to markets.

The framework in Figure 3.1 places these risks in three BoP categories: exports, imports and external finance. It highlights how physical risks and transition risks can reinforce one another.

3.1. Exports: concentration in nature-dependent activities, and amplification through supply chains

Brazil's greatest area of exposure is in exports. As shown in Table 3.1 below, the country's export basket is concentrated in sectors in which ecosystem services are vital to production inputs. Agriculture is the single largest export sector – with oil and gas, mining and animal products also accounting for sizeable shares of exports. All these activities are closely tied to ecosystem services such as water regulation, precipitation patterns and soil conditions.

Table 3.1. Brazil's main exporting industries as a share of exports (2021)

Industry	Share of exports
Agriculture	16.78%
Iron ore extraction	13.85%
Oil and gas extraction	9.59%
Slaughter and meat products; dairy and fishery products	6.67%
Production of pig iron/ferroalloys; steelmaking and seamless steel tubes	4.64%

Sources: Kaltenbrunner et al. (forthcoming); Alves-Passoni and Freitas (2024); UNEP (2025).

Notes: Agriculture refers to raw agricultural commodities; other food products include processed agricultural products such as soy oil and processed coffee.

"Physical risks and transition risks can reinforce one another."

The Brazil case study adds two layers of detail to this broader picture:

- Direct dependence (sectors): agriculture has the highest number of high or very high dependencies (11) in the ENCORE-based mapping exercise, particularly in connection with water flow and quality, precipitation, pollination and soil formation. These ecosystem services directly affect yields and the reliability of export volumes.
- Upstream dependence (supply chains): accounting for input–output connections emphasises the exposure of several export-linked downstream sectors, especially food processing and biofuels, which inherit ecosystem-service dependence through agricultural inputs. This matters for the BoP because it broadens the set of tradables that are vulnerable to the changes in costs and reliability caused by nature degradation, even if the downstream sector is not obviously nature-based at first glance.

On the qualitative side, interviewees emphasised that nature degradation can reduce export competitiveness through a mix of lower yields, reduced quality and logistics disruptions that raise costs and heighten risk. They also flagged that, as is well established in the literature (e.g. Araujo and Mourão, 2023), deforestation is not a simple case of 'more land = more exports'. Because the Amazon is central to hydrological regulation, forest loss can undermine rainfall patterns and agricultural productivity in ways that reduce export performance (and can do so with long time delays and tipping dynamics, threshold effects beyond which further forest loss can trigger abrupt and self-reinforcing changes in the regional climate system).

Finally, transition and market-access channels can amplify physical shocks. For instance, the introduction of the EU's Deforestation Regulation (EUDR) raised compliance and certification costs, potentially constraining market access for companies that rely on deforestation-linked supply chains (Kaltenbrunner et al., forthcoming).[3]

Combining these elements, Figure 3.1 shows that a large share of Brazil's exports is concentrated in sectors that depend on ecosystem services, allowing nature shocks to quickly translate into FX pressure.

3.2. Imports: weaker direct exposure, but significant vulnerability through prices, logistics and energy

Brazil's top imports are largely industrial intermediates and capital goods (see Table 3.2.1 below). These products tend to have lower *direct* ecosystem-service dependence than exports, according to ENCORE scores.

Table 3.2.1. Brazil's main importing industries (share of imports)

Industry	Share of imports
Manufacture of organic and inorganic chemicals, resins and elastomers	12.17%
Manufacture of computer equipment, electronics and optical products	8.91%
Manufacture of mechanical machinery and equipment	6.37%
Manufacture of other transport equipment, except motor vehicles	6.28%
Oil refining and coke plants	5.36%

Sources: Kaltenbrunner et al. (forthcoming); Alves-Passoni and Freitas (2024); UNEP (2025).

Therefore, as the mapping exercise indicated, the vulnerability of Brazil's BoP to nature degradation is skewed towards export shocks rather than immediate import-side physical constraints. That said, imports are still important to the country's macroeconomic position in at least three ways:

- Depreciation pass-through. Import costs automatically rise if nature stress weakens exports and triggers depreciation, even if the imported items are not directly dependent on nature.
- Input bottlenecks. Supply disruptions or price spikes in key intermediates and capital goods can erode future export capacity by constraining maintenance, investment and productivity upgrades in export sectors.
- Energy and logistics stress. Interviewees linked low river levels, shortfalls in hydropower and flood-related stoppages to disruptions in transport and energy networks – channels that can increase imported fuel needs and raise the cost of imported production inputs.
- Insurance, freight and adaptation costs. As the risk of disruption rises, firms and the public sector may face increases in insurance premia, freight and shipping costs and spending on emergency response and adaptation – pressures that can result in higher services imports and fiscal–external stress, especially after repeated extreme climate events.

"Because the Amazon is central to hydrological regulation, forest loss can undermine rainfall patterns and agricultural productivity in ways that reduce export performance."

[3] This concern also appears in Keane et al. (2025), which looks at the potential macroeconomic impacts of the EUDR on Honduras.

A key caveat is that nature degradation can also raise import dependence if domestic production of essential goods (including food) becomes less reliable and needs to be substituted through imports. It is plausible that simultaneous nature-driven negative supply shocks across sectors could also tighten global markets and raise prices, increasing the pressure on Brazil's current account.

3.3. External financing: when nature risk affects risk premiums

Nature degradation can turn a trade shock into a financing shock. Table 3.3.1 below shows that a non-trivial share of FDI inflows is concentrated in sectors with high or very high ecosystem-service dependence (e.g. metallic minerals, utilities, transport and storage), which can feed back into the financial system. Nature degradation can raise operational risk (through water scarcity, energy insecurity and logistics disruption) and increase regulatory and reputational uncertainty, tightening financing conditions just as FX earnings come under pressure.

Table 3.3.1. Brazilian sectors with the largest foreign direct investment inflows (2023)

Industry	Share of FDI inflows in 2023	Number of ecosystem services sector at least highly dependent on
Financial services and auxiliary activity	11.70%	0
Trade, except for motor vehicles	11.36%	1
Extraction of metallic minerals	10.03%	4
Electricity, gas and other utilities	9.45%	8
Other services	4.92%	0
Storage and auxiliary transport activities	4.84%	4
Transport	4.09%	3
Insurance, reinsurance, complementary pensions and health plans	4.04%	0
Financial services – non-financial holdings	3.88%	0
Information technology services	3.79%	0

Sources: Kaltenbrunner et al. (forthcoming); Banco Central do Brasil, 2025; UNEP, 2025.

This exposure extends beyond FDI. Nature-related risk can propagate through portfolio flows and cross-border credit, raising sovereign and corporate spreads, reducing the ability to refinance existing debt and triggering outflows from local-currency bond and equity markets. Income flows can also raise these pressures: when profits are squeezed or uncertainty rises, firms may adjust dividend and intra-firm payment patterns, increasing profit repatriation and worsening the income balance at an inopportune moment. Such mechanisms matter because they can accelerate reserve losses and force sharper FX adjustment even if trade volumes adjust more gradually.

Interviewees emphasised that this 'financing channel' is, therefore, macroeconomically important but conditional. If investors internalise ecosystem-service dependence – especially due to repeated extreme climate events, or to perceived inconsistency in governance – FDI and other inflows may weaken or become more volatile, compounding BoP stress. Conversely, credible and predictable environmental governance can support financing by reducing uncertainty and enabling investment in more resilient value chains and infrastructure, even if it initially discourages some high-risk activities.

> "Nature degradation can raise operational risk and increase regulatory and reputational uncertainty."

4. Cross-country evidence: exposure mapping and exchange-rate tail risks

The Brazil case study demonstrates how nature degradation can translate into external economic pressure on a particular country. The cross-country evidence shows the areas in which that structural vulnerability is likely to be most acute across Latin America.

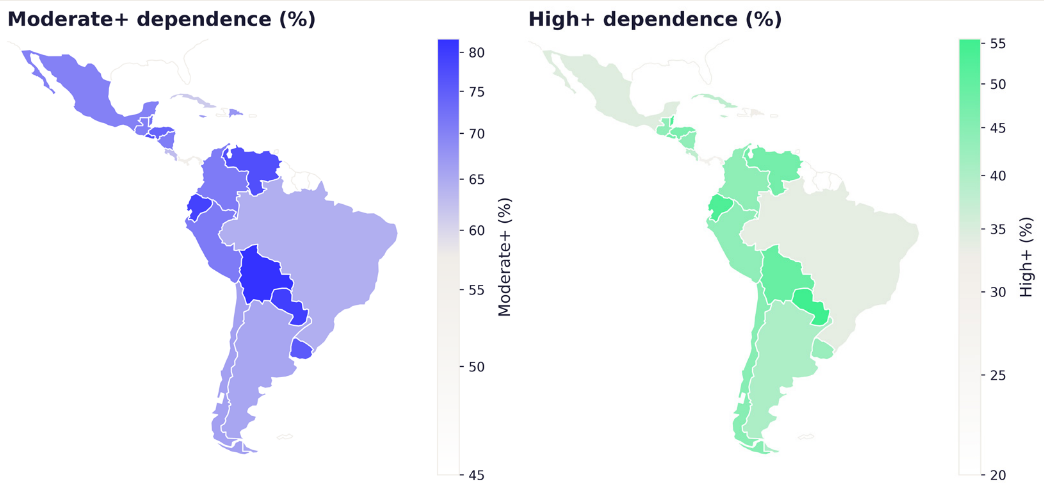
4.1. Moderate exposure is widespread, but high exposure is concentrated in commodity- and land-intensive economies

The exposure mapping exercise estimates, for each country, the share of total output[4] produced by activities that are at least moderately, highly or very highly dependent on ecosystem services. These cut-offs are nested (e.g. 'high+' includes 'very high') for ease of comparison: 'moderate+' signals broad exposure while 'very high' is a marker of acute macroeconomic vulnerability. Figure 4.1.1 and Table 4.1.1 below show a clear pattern for Latin America:

- There is moderate+ dependence across the regional economy. Even the least exposed national economy in the table has 46.5% of output at least moderately dependent on ecosystem services, while the most exposed is at 81.8%. This is because water regulation, soil quality and other ecosystem services are upstream inputs that matter across many sectors, be it directly or indirectly.
- High+ dependence differentiates countries more sharply. In Latin America, the high+ share averages around 41%, with a range of roughly 22% to 56%. This is where structural differences in production models become more visible, especially between land- and commodity-intensive economies and more diversified ones.
- A smaller number of 'tail' economies have very high dependence. The regional average is around 21%, with a range from 5% to 32%. In countries near the top of this range (e.g. Paraguay and Ecuador), ecosystem-service reliance is not just widespread but deeply embedded in the sectors that drive aggregate production.

"Water regulation, soil quality and other ecosystem services are upstream inputs that matter across many sectors."

Figure 4.1.1. Dependence on ecosystem services in Latin America



Data sources: Klein Martins et al. (forthcoming); UNEP, 2025; Kulionis et al., 2024; Lenzen et al., 2022.

[4] This metric measures economy-wide dependence, not just the externally oriented (trade) component. Brazil does not appear to be highly exposed in this indicator because its domestic production is relatively diversified, with a large services share. Yet Brazil's does have high export exposure, as its export basket is heavily reliant on agricultural goods.

Table 4.1.1. Output-based exposure to ecosystem-service dependence in Latin America

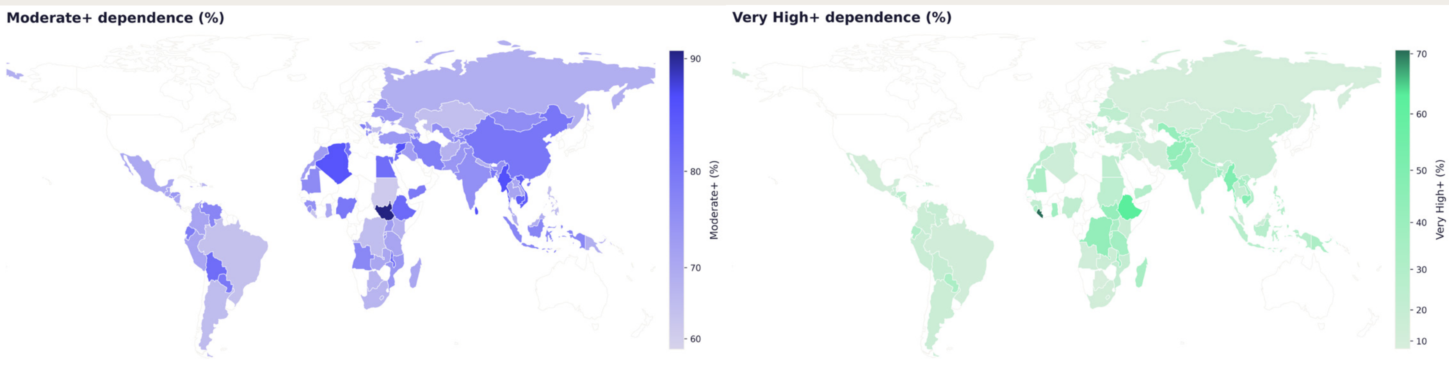
Country	Moderate+ output share	High+ output share	Very high output share
Bolivia	81.78%	49.44%	23.87%
Paraguay	79.63%	55.54%	32.22%
Ecuador	79.08%	53.38%	30.92%
Venezuela	77.18%	47.60%	20.30%
El Salvador	77.16%	47.47%	29.50%
Honduras	74.20%	46.59%	30.60%
Belize	71.93%	52.77%	21.65%
Mexico	70.23%	34.38%	14.01%
Chile	66.29%	44.83%	17.90%
Argentina	65.52%	40.04%	21.33%
Brazil	64.35%	33.72%	16.37%
Cuba	61.23%	37.94%	31.28%
Panama	55.30%	28.35%	17.02%
Bahamas	46.53%	22.13%	5.17%

Sources: Klein Martins et al. (forthcoming); ENCORE and GLORIA mapping; UNEP, 2025; Kulionis et al., 2024; Lenzen et al., 2022.

Using the same method to analyse 84 EMDE countries, Figure 4.1.2 below reveals a clear pattern: dependence on ecosystem services is widespread at the moderate threshold, but becomes increasingly concentrated as one moves to high and especially very high dependence, generating a distinct 'tail' of economies in which nature-linked activities account for a very large share of aggregate production. At the moderate threshold, there is broad exposure across the Global South. Such exposure sometimes reaches strikingly high levels: South Sudan is an extreme example (close to 91% of output) while several economies in the Middle East, North Africa, South Asia and Southeast Asia also rank near the top. These include Syria, Sri Lanka, Myanmar, Algeria, Vietnam and Cambodia (generally in the mid-80% range). Latin America is most visible at this level through Bolivia (82%), Paraguay (80%) and Ecuador (79%), indicating that large shares of production in these land- and commodity-intensive economies are linked to activities dependent on ecosystem services.

"Large shares of production in these land- and commodity-intensive economies are linked to activities dependent on ecosystem services."

Figure 4.1.2. Ecosystem-service dependence in select developing economies



Data sources: Klein Martins et al. (forthcoming); UNEP, 2025; Kulionis et al., 2024; Lenzen et al., 2022.

The distribution becomes more selective and strongly concentrates in Sub-Saharan Africa and South/Southeast Asia (with smaller clusters in the Middle East, North Africa and Central Asia). This implies that moving from moderate to high or very high dependence does not simply scale down all countries proportionally but instead separates a smaller subset of economies in which ecosystem services are structurally important to production – and, therefore, likely more exposed to ecological damage. This tail concentration is clearest in the very high category, where Ethiopia (63%) and Malawi (60%) stand out, followed by Myanmar (54%), South Sudan (53%) and Cambodia (51%). Other countries such as Tajikistan, Burundi, Vietnam, Nepal, Afghanistan, Bangladesh and Pakistan are also markedly exposed even under the strictest threshold.

Taken together, the mapping exercise suggests that the most extreme dependence is concentrated in economies whose production structures remain tightly linked to agriculture, forestry, fisheries and other nature-dependent activities. Moreover, the persistence of high or very high dependence appears to come from structural reliance rather than broad but shallow exposure, indicating heightened vulnerability to ecosystem degradation, climate shocks and related supply disruptions.

“The most extreme dependence is concentrated in economies whose production structures remain tightly linked to agriculture, forestry, fisheries and other nature-dependent activities.“

4.2. Exchange-rate tail risks: indicative but mixed evidence

The econometric component of this study tests whether nature degradation is associated with exchange-rate tail risks. The clearest and most consistent pattern appears in the volatility results: cumulative losses in biocapacity are associated with larger exchange-rate changes in the full sample, including in the upper tail. In Latin America, the relationship is clearer around the median than in the extreme tail (higher volatility). This is consistent with the observation that in Latin America, large devaluations are often dominated by global financial shocks and domestic macroeconomic events that can overshadow slow-moving ecological signals in the short term.[5] Over time, persistent nature degradation can cause ecosystems to reach a tipping point, destabilising production in ways that have significant macroeconomic impacts.

Table 4.2.1. Quantile regressions of the effect of biocapacity on exchange-rate volatility

Biocapacity variable	Coef p50	Coef p95
Full sample		
Level	0.0002	0.0017*
Cumulative % change	-0.0158***	-0.0276***
Latin America		
Level	0.0012***	0.0012
Cumulative % change	-0.0323***	0.0013

*Note: *** indicates statistically significant at 1% significance level, and * at 10%.*

The results are weaker and more sensitive when the outcome is defined as devaluation rather than magnitude (see Table 4.2.2 below), particularly in Latin America. For policymakers, the main insight is not that biocapacity predicts crises, but that nature degradation can worsen the distribution of external-adjustment outcomes in economies where production is structurally dependent on nature. The limitations detailed in Box 4.1 below indicate why this effect is difficult to clearly identify.

[5] We included standard controls for global financial conditions and domestic macroeconomic fundamentals, accounting for country and time effects as appropriate. Full variable definitions, sample construction and robustness checks are included in the Annex.

Table 4.2.2. Quantile regressions of exchange-rate devaluation on biocapacity

Biocapacity variable	Coef p50	Coef p95
Full sample		
Level	0.0033	0.0079
Cumulative % change	0.0034	0.0274*
Latin America		
Level	0.0025	0.0645
Cumulative % change	-0.0076	-0.0997

Box 4.1. The challenge of estimating the effect of ecosystem-services loss on exchange rates

This econometric exercise faces tight data and identification constraints. Our most direct structural exposure measure – ecosystem-services dependence constructed from ENCORE and input–output structure – is effectively time-invariant at the country level over the period we study. Given that there is little within-country variation in the key explanatory variable (i.e., each country has only one ecosystem services dependence score), the number of de facto observations is limited, and estimates tend to be sensitive to specification choices.

Therefore, to introduce significant time variation, we use biocapacity (Lo et al., 2025) as a time-varying proxy for changes in ecological capacity and the loss of ecosystem services. Unlike structural dependence measures, biocapacity can change year to year with climate conditions, land management and shifts in what is economically usable, making it more suitable for panel regressions.

Even with this adjustment, the signal is intrinsically hard to detect because the relevant ecological indicators are slow-moving, while exchange rates are high-frequency variables that respond quickly to many forces unrelated to nature, such as global financial conditions, commodity-price cycles, domestic policy credibility, political shocks and monetary and fiscal policy surprises. In the short term, these macro-financial shocks can dominate exchange-rate dynamics and overwhelm gradual ecological deterioration, biasing estimates toward weak or unstable results.

Finally, the economic effects of nature degradation may be non-linear and state-contingent: risks can accumulate quietly and then materialise through disruptions, thresholds and cascading interactions. As such, standard linear specifications and broad cross-country proxies may understate tail risks that are triggered episodically (e.g. droughts, floods, logistics disruptions) or amplified when buffers are low (e.g. tight reserves, stressed financing conditions). For these reasons, regression evidence should be treated as indicative and interpreted alongside structural exposure mapping (ENCORE and GLORIA), as well as the country-grounded evidence.

"Risks can accumulate quietly and then materialise through disruptions, thresholds and cascading interactions."

5. Policy implications and recommendations

Our findings point to a simple macroeconomic message: nature degradation can translate into BoP stress through export fragility and volatility, import-cost pressures (often via depreciation, and energy and logistics disruptions) and tighter external financing. In Brazil, deforestation-linked risks to hydrological regulation and rainfall have an especially significant macroeconomic impact because they sit upstream of major FX-earning sectors and can trigger market-access and reputational shocks. Even when the cross-country econometric evidence is mixed, there is an imperative for policymakers to enhance risk-management by building buffers, improving information exchanges and reducing the probability that ecological shocks will force abrupt FX adjustments. The following recommendations outline how policymakers can act on these risks.

Central banks and financial supervisors

In the near term, central banks and financial supervisors should:

- **Integrate nature-related supply shocks into inflation forecasting, FX risk assessment and policy communication.** This involves embedding droughts, water stress and logistics disruption scenarios into inflation and external-sector analysis (including food, energy and exchange-rate pass-through) and communicating how the inflation-targeting framework will respond. Policymakers should distinguish between transitory relative-price shocks and broader second-round effects on expectations, wages and core inflation. This would help preserve credibility while reducing the risk of unnecessary tightening during BoP stress.
- **Pilot BoP stress tests with nature scenarios.** It is important to map plausible shocks (rainfall volatility, droughts, hydropower shortfalls, logistics disruptions) into export, import and financing stress paths, to assess reserve adequacy and FX liquidity needs.
- **Strengthen supervision of nature-exposed FX and funding risks.** Institutions should be required to map exposures where high ecosystem-service dependence coincides with FX debt, foreign investor concentration or collateral risk.

“Institutions should be required to map exposures where high ecosystem-service dependence coincides with FX debt, foreign investor concentration or collateral risk.“

In the medium term, central banks and financial supervisors should:

- **Build a 'nature–BoP' data backbone.** This involves developing sector-level data on BoP-relevant flows (trade, FDI, portfolios, cross-border credit, income payments) linked to ecosystem-service exposure, to support early warning of FX risk and external-financing pressure.
- **Map the supply chain–finance–nature nexus.** Nature shocks can disrupt supply chains and tighten funding at the same time, while stress on supply chains can feed back into financial vulnerabilities. More granular data on instruments, sectors, actors and residency is needed to identify the key transmission channels and enable joint monitoring.
- **Update the climate-risk zoning used in agricultural credit.** Policymakers should modernise and routinely update the crop–climate risk maps used in agricultural credit and insurance (e.g. ZARC[6] in Brazil), reduce mispriced credit and future non-performing loans after drought or heat shocks, and limit spillovers from farm stress into the financial system and the broader economy.
- **Link exposure to prudential expectations.** Banks or investors that are heavily exposed to nature-dependent sectors require stronger FX liquidity management, clearer hedging and margining practices, and routine stress testing. This would mean that shocks were less likely to amplify sudden stops and forced FX adjustment.

[6] The Agricultural Climate Risk Zoning (ZARC) initiative is a federal technical instrument that maps, by municipality and planting calendar, the recommended sowing windows and conditions with lower climatic risk. This helps guide policy in areas such as rural credit and agricultural insurance.

- **Support local-currency development finance for resilience and upgrading.** Central banks and supervisors should work with public development banks to expand affordable local-currency financing for investments that reduce BoP vulnerability (e.g. water resilience, energy reliability, logistics and upgrades of macroeconomically important export chains), while tightening risk management expectations for private lending to highly exposed activities.

Finance ministries and fiscal authorities

In the near term, finance ministries and fiscal authorities should:

- **Operationalise disaster escape clauses in fiscal frameworks.** The aim of this would be to avoid pro-cyclical tightening after shocks that can simultaneously hit exports, raise import costs and tighten financing.
- **Pre-design temporary stabilisers for food and essentials aftershocks.** Targeted temporary support, including the use of public food stocks to smooth price spikes (e.g. CONAB[7] in Brazil), can limit second-round inflation and reduce the pressure for pro-cyclical tightening under FX stress.
- **Re-target incentives away from nature-degrading activities.** This requires an effort to phase out harmful subsidies (e.g. fossil-fuel tax breaks and diesel-based generation in isolated systems, and subsidised rural credit that is not conditioned on verified zero-deforestation compliance) and redirect them towards restoration and resilience. It also requires better traceability of subsidised credit to support governance credibility.

In the medium term, finance ministries and fiscal authorities should:

- **Treat deforestation control and ecosystem protection as macro-stability spending.** In Brazil, for instance, safeguarding hydrological regulation helps protect FX earnings and reduces BoP adjustment pressure.
- **Plan fiscal responses for compound shocks (global tightening plus ecological disruption) in coordination with the central bank.** This includes pre-arranging contingency financing and emergency budget instruments (e.g. precautionary credit lines and rapid-disbursement facilities) to prevent ecological shocks from forcing pro-cyclical fiscal cuts or abruptly increasing pressure on reserves, interest rates and the exchange rate.

Cross-government coordination on environment, agriculture, infrastructure and finance

In the near term, government institutions should:

- **Create a shared early-warning and response function for nature-related external risk.** This could involve establishing an inter-agency monitoring mechanism that combines environmental indicators (deforestation, water stress, soil risk), external exposure indicators (key export chains, FDI, financing dependence) and market stress signals (FX pressure, spreads, foreign investor flows) to help coordinate decision-making during shocks.
- **Scale traceability in key export chains.** This requires strengthened coordination across environmental enforcement, agriculture, trade and customs to expand traceability systems that verify deforestation-

"Targeted temporary support can limit second-round inflation and reduce the pressure for pro-cyclical tightening under FX stress."

[7] Companhia Nacional de Abastecimento is a federal enterprise that, among other functions, manages public stocks of agricultural commodities, including grains.

free supply. Such efforts would help protect market access and reduce financing risks linked to reputational, environmental, social and governance (ESG) issues – risks that could weaken export receipts and external financing at the same time.

In the medium term, government institutions should:

- **Institutionalise inter-agency shock-response protocols.** To prevent fragmented responses that amplify BoP stress, government institutions should predefine who does what when nature shocks hit. This should cover environmental monitoring and alerts, logistics prioritisation, trade facilitation, emergency support to avoid cascading defaults, and public communication.
- **Coordinate investment in macro-critical resilience bottlenecks.** This could be achieved by using cross-government planning to prioritise infrastructure and adaptation in systems that are vital to external stability (e.g. water systems, transport corridors, energy reliability), especially where disruptions can simultaneously affect exports and import costs.
- **Coordinate a nature-resilient structural transformation strategy.** Environment, agriculture, industry, infrastructure, trade and financial authorities should jointly define priority sectors and major bottlenecks in a transition away from highly vulnerable, deforestation-linked production and towards more resilient, higher value-added activities. This would create a clear roadmap for fiscal policymakers, public development banks, and financial regulators to support sectoral upgrading while reducing long-term BoP and FX vulnerability.

"To prevent fragmented responses that amplify BoP stress, government institutions should predefine who does what when nature shocks hit."

International financial institutions

In the near term, the International Monetary Fund (IMF) and multilateral development banks should:

- **Treat nature risks as macro-critical in surveillance and programmes.** For highly exposed economies, this involves explicitly assessing external sustainability (exports, import costs, financing) and its interactions with global financial cycles.
- **Expand technical assistance for data and stress testing.** This involves support in building data on sectoral exposure accounts, foreign investor positions and nature-linked credit concentrations, as well as integrating nature metrics into programme design, conditionality and monitoring (Forster et al., 2024).

In the medium term, the IMF and multilateral development banks should:

- **Develop contingent liquidity instruments for ecological shocks.** Rapid-disbursement facilities can limit reserve losses and FX overshooting, especially when shocks coincide with tight global conditions.
- **Provide affordable local-currency financing for climate adaptation and structural transformation.** This could occur via public development banks, guarantees and blended finance to reduce FX and rollover risk, as well as efforts to crowd in long-term investment that lowers climate vulnerability.

References

Adrian T, Boyarchenko N, Giannone D (2019) Vulnerable growth. *American Economic Review* 109(4): 1,263–1,289. https://doi.org/10.1257/aer.20161923

Althouse J, Guarini G, Gabriel Porcile J (2020) Ecological macroeconomics in the open economy: sustainability, unequal exchange and policy coordination in a center-periphery model. *Ecological Economics* 172: 106628. https://doi.org/10.1016/j.ecolecon.2020.106628

Althouse J, Bedossa B, Espagne E, Faucher L, Gonon M, Kedward K, Modica Scala A, Poupard A, Svartzman R (2025) *From climate to nature macro-criticality: exploring new scenarios and modelling frameworks.* Discussion Paper 19,987. London: CEPR.

Alves-Passoni P, Freitas F (2024) Estimação de matrizes insumo-produto anuais para o Brasil no sistema de contas nacionais: Referência 2010. *Pesquisa e Planejamento Econômico* 53: 117–165. https://doi.org/10.38116/ppe53n1art4

Araujo R, Mourão J (2023) *The Amazon domino effect: how deforestation can trigger widespread degradation.* Rio de Janeiro: Climate Policy Initiative.

Arslanalp S, Tsuda T (2014) *Tracking global demand for emerging market sovereign debt.* IMF Working Paper WP/14/39. Washington, DC: International Monetary Fund. https://doi.org/10.5089/9781484326541.001

Banco Central do Brasil (2025) Investimentos diretos no país – distribuição por setor. https://www.bcb.gov.br/estatisticas/tabelasespeciais

Boldrini S, Ceglar A, Lelli C, Parisi L, Heemskerk I (2023) *Living in a world of disappearing nature: physical risk and the implications for financial stability.* Occasional Paper 333. Frankfurt: European Central Bank.

Bonato M, Cepni O, Gupta R, Pierdzioch C (2023) Climate risks and realized volatility of major commodity currency exchange rates. *Journal of Financial Markets* 62: 100,752. https://doi.org/10.1016/j.finmar.2022.100752

Bonizzi B, Kaltenbrunner A, Pache A-C, Perez C, Powell J (forthcoming) *Commodity price booms and busts in low- and middle-income countries: an asymmetric tail risk analysis*

Bortz PG, Toftum N (2024) Changes in rainfall, agricultural exports and reserves: macroeconomic impacts of climate change in Argentina. *Journal of Environmental Economics and Policy* 13(2): 243–258. https://doi.org/10.1080/21606544.2023.2236987

Boyd J, Banzhaf S (2007) What are ecosystem services? The need for standardized environmental accounting units. *Ecological Economics* 63(2): 616–626. https://doi.org/10.1016/j.ecolecon.2007.01.002

Calice P, Diaz Kalan F, Miguel F (2021) *Nature-related financial risks in Brazil.* Policy Research Working Paper 9,759. Washington, DC: World Bank. https://doi.org/10.1596/1813-9450-9759

Calice P, Kalan FD, Dunz N, Miguel F (2023) *Biodiversity and finance: a preliminary assessment of physical risks for the banking sector in emerging markets.* Policy Research Working Paper 10,432. Washington, DC: World Bank.

Cashin P, Céspedes L, Sahay R (2004) Commodity currencies and the real exchange rate. *Journal of Development Economics* 75: 239–268. https://doi.org/10.1016/j.jdeveco.2003.08.005

Cheema-Fox A, Serafeim G, Wang H (2022) Climate change vulnerability and currency returns. *Financial Analysts Journal* 78(4): 37–58. https://doi.org/10.1080/0015198X.2022.2100233

Chen Y, Rogoff K (2003) Commodity currencies. *Journal of International Economics* 60(1): 133–160. https://doi.org/10.1016/S0022-1996(02)00072-7

Costanza R, de Groot R, Sutton P, van der Ploeg S, Anderson SJ, Kubiszewski I, Farber S, Turner RK (2014) Changes in the global value of ecosystem services. *Global Environmental Change* 26: 152–158. https://doi.org/10.1016/j.gloenvcha.2014.04.002

Drechsel T, Tenreyro S (2018) Commodity booms and busts in emerging economies. *Journal of International Economics* 112: 200–218. https://doi.org/10.1016/j.jinteco.2018.01.002

Eguren-Martin F, Sokol A (2022) Attention to the tail(s): global financial conditions and exchange rate risks. *IMF Economic Review* 70(3): 487–519. https://doi.org/10.1057/s41308-022-00160-0

Fernández A, González A, Rodríguez D (2018) Sharing a ride on the commodities roller coaster: common factors in business cycles of emerging economies. *Journal of International Economics* 111: 99–121. https://doi.org/10.1016/j.jinteco.2017.11.008

Gächter M, Geiger M, Hasler E (2023) On the structural determinants of growth-at-risk. *International Journal of Central Banking* 19(2): 251–293.

Hadji-Lazaro P, Salin M, Svartzman R, Espagne E, Gauthey J, Berger J, Calas J, Godin A, Vallier A (2024) Biodiversity loss and financial stability as a new frontier for central banks: an exploration for France. *Ecological Economics* 223: 107,955. https://doi.org/10.1016/j.ecolecon.2024.108246

Howarth RB, Farber S (2002) Accounting for the value of ecosystem services. *Ecological Economics* 41(3): 421–429. https://doi.org/10.1016/S0921-8009(02)00091-5

Instituto Brasileiro de Geografia e Estatística (2023) Correspondência entre CNAE e SCN. https://www.ibge.gov.br

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES] (2019) *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* Bonn: IPBES. https://doi.org/10.5281/zenodo.6417333

Kaltenbrunner A, Löscher A, Rodrigues I, Araujo K, Klein Martins G (forthcoming) *Nature degradation and external vulnerability in Latin America: insights from Brazil's balance of payments and exchange rate risks*.

Keane J, Arce B, Ayele Y, Raga S (2025) *Macroeconomic and financial risks transmitted by the European Union Deforestation Regulation: a focus on the coffee value chain in Honduras.* CETEx Discussion Paper Series: Land and Ocean, Policy Briefing Paper 6. London: Centre for Economic Transition Expertise, London School of Economics and Political Science.

Klein Martins G, Kaltenbrunner A, Löscher A, Rodrigues I, Araujo K (forthcoming) *Nature loss and macroeconomic vulnerability in developing countries: implications for balance of payments and exchange rate stability*.

Kulionis V, Pfister S, Fernandez J (2024) Biodiversity impact assessment for finance. *Journal of Industrial Ecology* 28(5): 1,321–1,335.

Kumar P, Brondizio E, Gatzweiler F, Gowdy J, de Groot D, Pascual U, Reyers B, Sukhdev P (2013) The economics of ecosystem services: from local analysis to national policies. *Current Opinion in Environmental Sustainability* 5(1): 78–86. https://doi.org/10.1016/j.cosust.2013.02.001

Laurinaitė N, Borges S (2023) *Assessing nature-related financial risks: the case of Lithuania.* Occasional Paper Series. Vilnius: Bank of Lithuania.

Lenzen M, Geschke A, West J, Fry J, Malik A, Giljum S, Milà i Canals L, Piñero P, Lutter S, Wiedmann T, Li M, Sevenster M, Potočnik J, Teixeira I, Van Voore M, Nansai K, Schandl H (2022) Implementing the material footprint to measure progress towards Sustainable Development Goals 8 and 12. *Nature Sustainability* 5(2): 157–166. https://doi.org/10.1038/s41893-021-00811-6

Lenzi D, Balvanera P, Arias-Arevalo P, Eser U, Guibrunet L, Martin A, Muraca B, Pascual U (2023) Justice, sustainability, and the diverse values of nature: why they matter for biodiversity conservation. *Current Opinion in Environmental Sustainability* 64: 101353. https://doi.org/10.1016/j.cosust.2023.101353

Lenton TM, Rockström J, Gaffney O, Rahmstorf S, Richardson K, Steffen W, Schellnhuber HJ (2019) Climate tipping points – too risky to bet against. *Nature* 575(7,784): 592–595. https://doi.org/10.1038/d41586-019-03595-0

Lo K, Miller E, Dworatzek P, Basnet N, Silva J, Van Berkum JL, Halldórsdóttir RB, Dyck MDR (2025) *National Ecological Footprint and Biocapacity Accounts, 2025 edition.* Version 1.0. Produced for Footprint Data Foundation by researchers at York University and the University of Iceland. https://footprint.info.yorku.ca/data/

Löscher A, Kaltenbrunner A (2023) Climate change and macroeconomic policy space in developing and emerging economies. *Journal of Post Keynesian Economics* 46(1): 113–141. https://doi.org/10.1080/01603477.2022.2084630

Löscher A, Kaltenbrunner A (2025) Climate risks, balance-of-payments constraints and central banking in emerging economies – insights from Nigeria. *Emerging Markets Review* 65: 101,255. https://doi.org/10.1016/j.ememar.2025.101255

Ministério do Desenvolvimento, Indústria, Comércio e Serviços (2022) *Estatísticas de comércio exterior.* https://www.gov.br/mdic/pt-br/assuntos/comercio-exterior/estatisticas

Nalin L, Yajima GT (2021) Commodities fluctuations, cross border flows and financial innovation: a stock-flow analysis. *Metroeconomica* 72(3): 539–579. https://doi.org/10.1111/meca.12333

Network for Greening the Financial System [NGFS] (2019) *A call for action: climate change as a source of financial risk.* First Comprehensive Report. Paris: NGFS. https://www.ebrd.com/cs/Satellite?c=Content&cid=1395281881639&d=&pagename=EBRD%2FContent%2FDownloadDocument

NGFS (2020) *The macroeconomic and financial stability impacts of climate change: research priorities.* Paris: NGFS. https://www.ngfs.net/sites/default/files/medias/documents/ngfs_research_priorities_final.pdf

NGFS (2022) *Central banking and supervision in the biosphere: an agenda for action on biodiversity loss, financial risks and system stability.* NGFS–INSPIRE Study Group on Biodiversity and Financial Stability. Paris: NGFS. https://www.ngfs.net/sites/default/files/medias/documents/central_banking_and_supervision_in_the_biosphere.pdf

NGFS (2024) *Nature-related financial risks: a conceptual framework to guide action by central banks and supervisors.* Paris: NGFS. https://www.ngfs.net/en/nature-related-financial-risks-conceptual-framework-guide-action-central-banks-and-supervisors

Poledna S, Martínez-Jaramillo S, Caccioli F, Thurner S (2021) Quantification of systemic risk from overlapping portfolios in the financial system. *Journal of Financial Stability* 52: 100808. https://doi.org/10.1016/j.jfs.2020.100808

Ranger N, Oliver T, Alvarez J, Battiston S, Bekker S, Killick H, Hurst I, Liadze I, Millard S, Monasterolo I, Perring M, Sabuco J, Sanchez Juanino P, Vause J, Verhoef A, Wolstenholme J (2024) *Assessing the materiality of nature-related financial risks for the UK.* London: Green Finance Institute.

Sockin M, Xiong W (2015) Informational frictions and commodity markets. *Journal of Finance* 70(5): 2,063–2,098. https://doi.org/10.1111/jofi.12261

Svartzman R, Bolton P, Després M, Pereira Da Silva LA, Samama F (2021) Central banks, financial stability and policy coordination in the age of climate uncertainty: a three-layered analytical and operational framework. *Climate Policy* 21(4): 563–580. https://doi.org/10.1080/14693062.2020.1862743

Svartzman R, Althouse J (2022) Greening the international monetary system? Not without addressing the political ecology of global imbalances. *Review of International Political Economy* 29(3): 844–869. https://doi.org/10.1080/09692290.2020.1854326

United Nations Convention to Combat Desertification [UNCCD] (2022) *Global Land Outlook 2*, 2nd edition. Bonn: UNCCD. https://www.unccd.int/resources/global-land-outlook/global-land-outlook-2nd-edition

UNCCD (2024) *Three-quarters of Earth's land became permanently drier in last three decades.* Bonn: UNCCD. https://www.unccd.int/sites/default/files/2024-12/PR%20aridity%20report.pdf

UN Environment Programme (2025) *ENCORE.* https://www.encorenature.org/en

Van Huellen S, Palazzi RB (2023) *Commodity currencies: unpicking the asymmetric relationship between commodity prices and exchange rates.* https://ssrn.com/abstract=4628629

World Economic Forum (2023) *Climate-vulnerable countries need better recovery support to avoid debt: here are some measures that can help.* Web page. https://www.weforum.org/agenda/2023/10/countries-recovering-from-climate-disasters-forced-into-debt-crises/

World Wide Fund for Nature (2024) *Living Planet Report 2024: a system in peril.* Gland: WWF. https://wwflpr.awsassets.panda.org/downloads/2024-lpr-executive-summary.pdf

Appendix

A. Technical methods and data

This Appendix details the qualitative and quantitative methods used in the two underlying studies. The core objective is to identify policy-relevant transmission channels from nature degradation and ecosystem-service loss to the balance of payments (BoP) and exchange-rate dynamics, and to triangulate those channels with sectoral exposure measures.

A1. Qualitative analysis: semi-structured interviews

We conducted twelve semi-structured interviews with experts – primarily researchers and practitioners working in finance, environmental planning/engineering and public policy. Sampling combined strategic selection and snowballing to cover biomes and regions where ecosystem-service dependence is salient, and sectors typically exposed to ecosystem-service disruption. Interviews were conducted in English and Portuguese between June and November 2025. They were recorded (with consent), transcribed and coded by the research team.

Coding focused on three policy-relevant dimensions:

1. Salient risks related to nature degradation and ecosystem-service loss (e.g. water stress, soil degradation, deforestation-related precipitation regulation changes, biodiversity-related productivity risks).
2. Sectoral dependencies and transmission mechanisms from ecosystem-service disruption to prices, quantities and logistics (including production constraints, supply-chain bottlenecks and input-cost shocks).
3. External-sector channels linking these disruptions to the BoP and the exchange rate (exports, imports, income and financial flows, and risk-premium and financing channels).

The interview evidence served two purposes. First, it shaped the theoretical framework by identifying the most salient nature–macroeconomic channels in Brazil. Second, it informed the quantitative mapping by guiding which sectors and external-account components were most relevant to assessing exposure and potential BoP sensitivity.

Table A1 provides an overview of the interviews, as well as the interviewees' professional backgrounds and affiliations.

Table A1. Interviewees

Interview number	Professional background	Date	Method of interview
1	Research economist in international development finance institution	27 June 2025	Online via Jitsi
2	Research economist at an international organisation consulting policymakers on climate finance and policymaking	14 July 2025	Online via Jitsi
3	Climate scientist at a German research institute	15 July 2025	Online via Jitsi
4	Researcher and consultant; trained as an agricultural engineer at a Brazilian university	16 July 2025	Online via Jitsi
5	Scientist working on biodiversity at the University of Cape Town	18 July 2025	Online via Jitsi
6	Economist at an international development finance institution	23 July 2025	Online via Jitsi
7	Climate scientist at a Swedish research institute	28 July 2025	Online via Jitsi
8	PhD researcher at an Italian university working on issues related to climate and development	29 July 2025	Online via Jitsi
9	Economist at an international development finance institution		
10	Research associate at a British institute working on the environment and resilience	9 Sept 2025	Online via Jitsi
11	PhD researcher at an Italian university and consultant working on transition risks in Brazil at the World Bank	15 Sept 2025	Online via Jitsi
12	Senior associate at an international think-tank working on climate finance	27 Nov 2025	Online via Jitsi

A2. Quantitative analysis: ENCORE, input–output tables, and sectoral BoP data

The quantitative analysis connected the insights gained from interviews with data that capture Brazil's exposure to ecosystem-service loss through its productive structure and external accounts. The approach proceeded in three steps: measuring sectoral ecosystem-service dependence; propagating dependence through upstream linkages using input–output (I–O) structure; and combining sectoral dependence/exposure with sector-level external-account data (trade and financial flows) to assess the BoP components' potential sensitivity to nature degradation.

A2.1 Ecosystem-service dependence (ENCORE) and sector classification

Sectoral dependence on ecosystem services was measured using the Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE) database, which reports dependence ratings across 21 ecosystem services based on expert assessments and quantitative inputs. The dependence categories were null, very low (VL), low (L), medium (M), high (H) and very high (VH). These categories were not country-specific; they described typical production-process reliance on ecosystem services.

ENCORE maps production processes to ISIC sectors. To integrate ENCORE into Brazilian I–O data, additional concordances were required. Because there is no direct International Standard Industrial Classification (ISIC) in the correspondence of Sistema de Contas Nacionais (SCN), the Brazilian National Accounts System, we proceeded via an intermediary mapping:

ISIC→CNAE (Classificação Nacional de Atividades Econômicas).[8]

CNAE→SCN (Sistema de Contas Nacional), matching the sectoral structure of the I–O tables.

Because CNAE does not separate public and private education and health, these sectors were merged, yielding a final set of 65 SCN sectors for the dependence calculations. Brazilian input–output tables were taken from Alves-Passoni and Freitas (2024); ENCORE data was sourced from UNEP (2025).

A2.2 From qualitative ratings to sector scores

ENCORE's qualitative ratings were transformed into percentage scores following Svartzman et al. (2021). When an industry was made up of more than one production process, a unique sector score was calculated through a simple mean. DS_s^e is the direct dependency score of sector 's' on a given ecosystem service 'e'. Denoting 'n' as the number of production processes 'k' involved in sector 's', and d_k^e the level of dependency of the production process 'k' to ecosystem services 'e', then Equation 1[9] is as follows:

$$DS_s^e = \sum_{k=1}^{n} \frac{d_k^e}{n} \qquad (1)$$

The entries obtained in Equation 1 formed the direct dependency matrix D, with 21 rows representing each of the ENCORE ecosystem services and 65 industry columns.

Stacking DS_s^e across ecosystem services and sectors yielded the direct dependence matrix Dof dimension 21×65, where each row corresponded to an ecosystem service and each column to an SCN sector.

A2.3 Upstream (indirect) dependence via input–output linkages

Upstream dependency scores, aggregated in a matrix U, were calculated by multiplying the matrix D of direct dependency scores by the matrix $\underline{L-I}$, with L representing the inverse Leontief matrix (or total requirements matrix) and I the identity matrix (Boldrini et al., 2023; Svartzman et al., 2021). In matrix $\underline{L-I}$, each coefficient of the $(L\text{-}I)$ matrix was divided by the sum of the $(L-I)$ coefficients in its column, reflecting the importance of each of the 65 economic sectors in the sector supply chain 's' (Svartzman et al., 2021). In this sense, the upstream dependency scores of a sector were the weighted average of the direct dependency scores of its suppliers:

$$U = D \times (\underline{L - I}) \qquad (2)$$

A2.4 Linking sectoral dependence to BoP components (Brazil)

In line with the general approach of the recent literature on nature-induced financial risks (e.g. Boldrini et al., 2023; Calice et al., 2021, 2023; Hadji-Lazaro et al., 2024; Laurinaitė and Borges, 2023; Poledna et al., 2021; Ranger et al., 2024; Svartzman et al., 2021), we combined the information on sectoral dependence on ecosystem

[8] CNAE (National Classification of Economic Activities) is the official Brazilian classification used to identify and organise the economic activities of firms and establishments in a way that is compatible with international standards.

[9] We used equations 1 and 2 from Svartzman et al. (2021: 29, 80), adapting the first by denoting the level of dependency with 'd' to reserve 'L' for the Leontief inverse matrix.

services from the ENCORE/input–output data with sector-specific BoP data. For the trade account, we used sectoral data from the Brazilian IO table and product data from Ministério do Desenvolvimento, Indústria, Comércio e Serviços (2022). For income and dividends, foreign direct investment, and portfolio flows, we used Banco Central do Brasil (2025). This gave us a comprehensive quantitative indication of the sensitivity of Brazil's balance of payments to nature degradation.

A.3 Cross-country analysis

To extend our analysis beyond Brazil, we used the Global Resource Input–Output Assessment (GLORIA) database, which provides environmentally-extended multi-regional input–output tables covering 164 regions and 120 sectors per region (Lenzen et al., 2022).

Econometric exercise

We followed the growth-at-risk literature (Adrian et al., 2019; Gächter et al., 2023) by using quantile methods to study how nature services relate to currency tail risk in developing economies, with a focus on Latin America. Unlike ordinary least squares (OLS), which estimates the conditional mean of the outcome variable, quantile regression estimates its conditional percentiles. Panel quantile regression (PQR) adapted this to panel data and accounts for quantile-specific fixed effects.

We used two main dependent variables. One is the quarterly depreciation rate of the bilateral nominal exchange rate relative to the US dollar. The second is the absolute value of the former. While the first is focused on strong depreciations, the second aims to capture exchange-rate volatility in more general terms. We estimated:

$$Q_{\Delta XR_{it}}(X_t, Z_{it}, Y_{it}) = \alpha_{i\tau} + \sum_{k=0}^{p} \square\, \beta_{k\tau} X_t + \delta_\tau Z_{it-1} X_t + \gamma_\tau Z_{it-1} + \theta'_\tau Y_{it-1},$$

Q denotes the τ-th conditional quantile, $\alpha_{i\tau}$ are country fixed effects that might vary with τ. X_t measures global shocks, Z_{it} is a country-specific index of change in nature services, and Y_{it} is a vector of macroeconomic controls.

Our econometric analysis used two related samples. The first was a broad, unbalanced panel of quarterly observations from the first quarter of 1990 to the fourth quarter of 2022, covering 56 low- and middle-income countries for which we observed both biocapacity and exchange rates (full developing-country sample). The second is a Latin American subsample of 13[10] countries, which allowed us to examine whether the nature–FX link differed in a region that is both nature-intensive and structurally constrained by the BoP. In both samples, we excluded country–quarters with hard pegs or fully dollarised regimes.

For each country, we constructed variables capturing both global shocks and country-specific characteristics that could drive exchange rate behaviour. We incorporated the share of public debt held by foreign investors (FI) as a key financial vulnerability indicator. Using data from Arslanalp and Tsuda (2014) and updates, we further disaggregate this into debt held by foreign banks (BFI) versus foreign non-bank financial institutions (NBFIs). To capture structural dependence on commodities, we included each country's median share of commodities in total exports (CMEXP_MED) over the sample. We also used the Economic Complexity Index (ECI) as a summary of export diversification and sophistication. In the sample, we included standard macroeconomic differentials that often drive exchange rates, such as the interest rate differential (domestic policy rate minus the US Federal Reserve's funds rate) and the inflation differential (domestic CPI inflation minus US inflation).

We defined the exchange rate depreciation rate as the quarter-on-quarter log difference in the nominal bilateral exchange rate against the US dollar (IMF–IFS). Formally, this was ΔXR = log(XRt) – log(XRt-1), so that it approximated the percentage change in the value of the domestic currency per US dollar. A positive ΔXR meant the currency depreciated (it took more local currency to buy US$1), while a negative value meant it appreciated. By looking at the distribution of ΔXR across many countries and time periods, we assessed how frequently large depreciations occurred and which factors were present when they did.

[10] Chile was excluded from the regression sample due to data limitations in constructing the lagged values for the inflation differential control variable. Therefore, its data were not included in the regression, even though data for the other control variables were available.

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