

Coronavirus, macroeconomy, and forests: What likely impacts?

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ABSTRACT

Much uncertainty persists about how the coronavirus (COVID-19) and its derived crisis effects will impact both the economy and forests. Here we conceptualize a recursive model where an initial COVID-19 supply-side shock hits first the Global North that, mediated by country-specific epidemic management strategies and other (fiscal, monetary, trade) policy responses feeds through to financial markets and the real economy. Analytically we distinguish two stylized scenarios: an optimistic V-shaped recovery where effective policy responses render most economic damages transitory, versus a pessimistic pathway of economic depression, where short-run pandemic impacts are dwarfed by the subsequent economic breakdown. Economic impacts are transitioned from the global North to the South through trade, tourism, remittances and investment/capital flows. As for impacts on tropical forests, we compare the effects of past economic crises to early indicators for incipient trends. We find national income and commodity price effects to be torn between three forces: a contractive-inflationary supply-side shock, deflationary pandemic demand-side effects, and expansive-inflationary monetary and fiscal policy responses. We discuss how global forest outcomes will depend on how these macroeconomic battles are resolved, but also on geographical differences in deforestation dynamics. Reviewing recent fire and deforestation alerts data, as well as annual tree-cover loss data, we find that deforestation-curbing and -enhancing factors so far just about neutralized each other. Yet, country impacts vary greatly. Changing macroeconomic scenarios, such as fading out of huge economic stimulus packages, could change the picture significantly, in line with what our model predicts.

1. Introduction

1.1. Issues and hypotheses

Living through a global health and economic crisis such as the Coronavirus (COVID-19) pandemic is discomfiting to humanity at multiple levels. Yet, for those of us working as applied scientists, it also raises many interesting questions about the resilience of our societies in reacting to the stress test of the virus attack. One of these resilience questions is: what is happening to the environment, and to forests specifically?

Various spontaneous reactions have surfaced here. One is grounded in the strongly rooted belief that poor people will become poorer during the crisis and are thus pushed to overexploit their environments by necessity: “they cut because they must” (Eckholm et al., 1984:6). Another is the expectation that commercial opportunity-led deforestation will be curbed:

busting commodity markets will give at least a temporary break to nature, with forests suffering fewer attacks from opportunity-seeking investors (Butler, 2015). Hence, the underlying diagnostics of what typically causes forest loss – push versus pull factors – differ across observers.

At the policy level, a crisis might also present opportunities for pro-environmental change (Wunder, 2020), for instance, by accelerating the transition to a circular bioeconomy (Marchetti and Palahí, 2020). Post-COVID pro-forest action of ‘building back better’ is part of the European Green Deal (European Commission, 2020) and being solicited for a New Green Deal in the USA (Brownstein, 2020). The severity of the crisis and multiple demands for stimulus packages have also helped open the fiscal floodgates, further legitimized by the so-called Modern Monetary Theory (Wray, 2015) and Economics of Hope (Mazzucato, 2018). These argue for a new value concept, and a larger deficit financing of public spending in a model fostering green and inclusive growth.

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In this article, we look closer at the multiple causal factors and transmission mechanisms at stake, acting between the Global North and South, and between a pandemic shock, macroeconomics, land use, and forests. Our strategy will be to sketch the expected impacts of the coronavirus outbreak on national economies, first in the global North (including China) and then its spread in the South.¹ From there, we will look at the likely derived land-use and forest effects, especially in the tropics and subtropics.

1.2. A conceptual model

Fig. 1 describes the systemic blocks, which we will explain in this subsection, and then use them as an organizing thread throughout this article. We have developed a graphical, recursive ('top-to-bottom') model. Recursiveness means that if we get our macroeconomic predictions wrong, forest impacts will also need revisions; the reverse is not true, except for some caveats on longer-term forest-to-economy feedback loops (cf. Section 7).

Initially, an epidemic outbreak causes illness and death (demographic block), as well as a policy response to manage the epidemic (cf. Section 2). Through social distancing measures, the spread of the disease can be mitigated (flattening the curve), thus sparing human lives and delaying infection rates, yet also exacerbating short-term production shortfalls. Jointly, the two effects trigger a reduced availability of labor, as well as restrictions in the mobility of people, goods and services. This will curb production of certain goods and services, especially those that are labor- and/or transport-intensive. Although not our focus, we flag also some direct impacts on land use and forests in the North. We term these effects the *COVID-19 supply shock*.

As aggregate supply is impacted, incomes also decline for those who lose their jobs or cannot sell goods and services (Section 3). In addition, consumers will likely become more cautious, spending generally less for precautionary reasons, in the face of considerable uncertainties. Hence, a demand contraction effect will occur. Yet, government macroeconomic policy responses will be a moderating factor. During previous crises in this millennium, central banks lowered interest rates and injected additional liquidity into the economic system. Financial markets (Section 3.2.) are important in terms of mediating credit and wealth effects vis-à-vis the real economy: when economic agents come to lose faith in the economy's capacity to cope with a crisis, contracting credit and falling asset values can lead to systemic chain reactions such as defaults, runs on banks, and a deflationary spiral. The prevailing social mood will manifest itself strongly in the financial markets.

The systemic trade/external transaction block (Section 4) determines the economic transition mechanisms vis-à-vis the economies in the Global South. When the epidemic becomes a pandemic, thus affecting practically all trading partners that take similar restrictive steps, this will particularly hit products with complex global supply chains (e.g. the automobile industry). Commodity prices will influence the flows of imports and exports of goods, as will quantitative restrictions imposed by the coronavirus crisis (e.g. ships unable to deliver their merchandise to a port). In addition, tourism is a service sector earning large foreign exchange inflows into many Southern economies. Remittances from workers abroad are another such non-commodity flow of income, and some North-South return migration may occur. Foreign direct investments and North-South capital flows more broadly will also be affected.

With respect to crisis adjustment in the Global South (Section 5), we

¹ A North-South dichotomy is always simplified, by implicitly referring more to economic development level and capacity than geography (e.g. Australia, New Zealand, or Singapore in the Southern Hemisphere), and through large heterogeneity within "the South". Still, Southern countries have less capacity to implement economic stimulus policies counteracting COVID-19 effects. Notably China is 'Northern' in our model, being a main source of global commodity demand.

scrutinize trends relating closely to natural resource management, such as changes in poverty levels, urbanization, internal migration, food demand, etc. Macroeconomic crises will cut into government budgets for items like agriculture, national parks, road building, etc. – more so than in the North, given less options to borrow. Naturally, these changes in private demand and in public policies will affect Southern land use and forests, in terms of deforestation and forest degradation (Section 6). Finally, we will discuss the variability of net forest outcomes in weighting together different impacts (Section 7).

2. Pandemic management responses

First, COVID-19 has caused direct economic costs to Northern societies, in terms of incremental illnesses, health expenses and deaths, as well as lost productions from the supply shock (see above). Some initial laissez-faire strategies aimed for a herd immunity, e.g. in the UK, USA, Brazil, and Sweden (Milne, 2020), but determining immunity thresholds and the risk of developing new COVID varieties proved tricky (Hartnett, 2020). A clear case was thus made early on that curve-flattening strategies pay off (Ferguson et al., 2020; Pueyo, 2020).

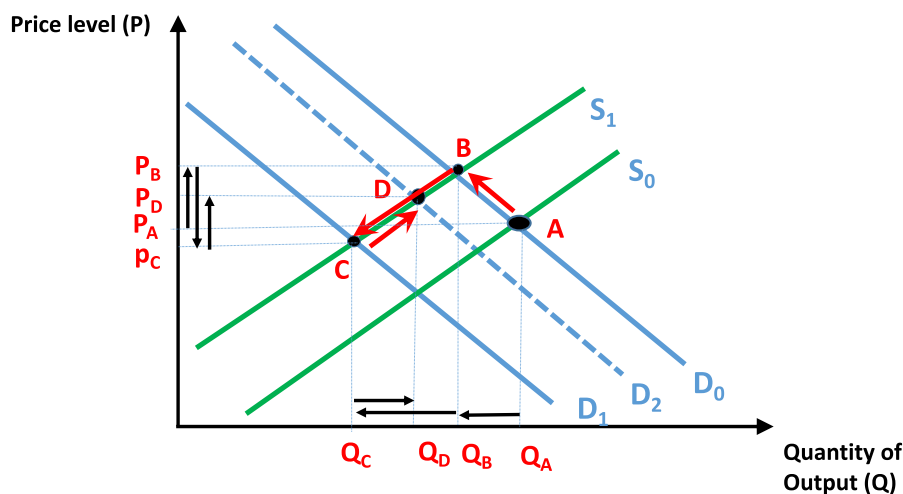
Second, indirect costs are incurred when adopted policies to mitigate viral spread (mandatory business and school closures, etc.) lead to economic lockdowns, i.e. large-scale social distancing (LSSD). While many governments have imposed lockdowns (Wikipedia, 2020), civil society also self-restrained activities, e.g. in Japan, Sweden, or Nicaragua, causing voluntary LSSD. Another pandemic strategy has been to screen, test, trace, and quarantine (STTQ) (Mulligan et al., 2020). Modelling of pandemic outcomes flagged STTQ action early on as the single most rewarding strategy component (isee systems, 2020). Early, rigorous STTQ adopters (e.g. South Korea, Taiwan, New Zealand) managed well the pandemic tradeoff with lockdown costs, compared to countries that relied heavily on LSSD (e.g. Italy, Spain) (Wangping et al., 2020). Nevertheless, rigorous STTQ encroached strongly on individual freedom. These ethical tradeoffs are conceived distinctively, so people come to advocate seemingly 'optimized' policy conclusions, yet based on antagonistically diverging objectives and criteria (Cashore and Bernstein, 2020).

Finally, at the current advanced stage of COVID-19 (end-May 2021), vaccination has globally emerged as the most effective pandemic strategy component, though with some insecurities vis-à-vis new COVID-19 varieties, as these emerge and spread. By Q3–2020, 128 vaccines were under development, 37 of which had reached human trials (Georgieva and Gopinath, 2020). Still, progress in vaccination throughout 2021 has been uneven, depending inter alia on countries' purchasing power and policies, organizational capacity, and civil society's willingness to accept vaccination offers when considering possible side effects.

The Global South is faced with similar choices regarding pandemic management, but has on average less economic capacity for stimulus packages (Section 5). Still, countries will also have a latecomer's advantage of learning from successes and mistakes in the richer, more mobile, and thus more quickly infected Global North. A few factors have widely slowed/mitigated COVID-19 impacts in the South: younger demographic profiles (less exposure to high mortality), lower intra-national mobility of citizens, less widespread obesity, and sometimes a warmer and drier climate (Fineberg, 2020).

This description masks obviously a large variability. India and Brazil rank second and third globally in absolute number of COVID-19 cases, but this reflects their large populations: they rank much lower according to the density of cases (#108, #36) and deaths (#110, #13). No developing country enters the top-ten of both density lists; no country from Sub-Saharan Africa enters the top-50 ranking (Worldometers, 2020).² As a caveat, COVID-19 cases and deaths are likely underestimated more in low-income countries with poor registries. Globally, 3.55 million COVID-

² The highest is South Africa, ranking #91 with respect to COVID-19 registered case density, and #53 for density of deaths (Worldometers, 2020).



Legend:

Point/ direction	Partial effect type	Price effect	Quantity effect
A	Pre-COVID equilibrium	n.a.	n.a.
A -> B	COVID supply shock	+	--
B -> C	Demand contraction	--	--
C -> D	Stimulus policies	+	+
A -> D	Net COVID effect	?	--

Fig. 2. Supply and demand effects of COVID.

19 deaths were official by end-May 2021 (Worldometers, 2020); a modelled range estimate of excess (otherwise inexplicable) deaths suggests instead 7.1–12.7 million lives lost (The Economist, 2021).

Early pandemic responses in many Southern countries have mimicked Northern LSSD policies; others have remained closer to laissez-faire (e.g. Brazil, Indonesia), but also then experienced frictions between federal and state-level strategies, and civil-society backlashes. Conversely, most low-income tropical countries have not yet had sufficient access to vaccines. They cannot sustain extreme LSSD measures for long: they are too poor to close their economies at length, trading-off differently between direct and indirect pandemic costs. Their economic policy faces the trilemma to manage simultaneous pressures to increase spending, relax burdening taxation, while not deteriorating already high public indebtedness – inevitably causing rises in domestic interest rates (Selassie and Tiffin, 2021).

3. Economic impacts in the North

3.1. Supply and demand

Financial media was quick to point out early that the COVID-19 economic crisis was fundamentally different from the 2008 financial crisis, the trigger being a production shortfall, rather than subprime asset owners and banks becoming insolvent. Fig. 2 depicts expected market supply- and demand-side effects from epidemic/pandemic cases, using a traditional supply-demand diagram determining aggregate production and price levels.³

³ The authors are grateful for inspiration on this figure to economist Henrik Zeberg (<https://www.thezebergreport.com>).

From the pre-COVID-19 equilibrium (point A), the pandemic shock pushes the supply curve upwards from S_0 to S_1 : at any given price, less is produced. With demand given by curve D_0 , the new intersection point B marks lower production and higher prices: across markets, the supply shock is inflationary. However, with reduced national production and income, demand would subsequently also be curbed (new curve D_1). This further depresses output (point C), while this partial price impact is deflationary: lower demand makes goods and services cheaper. Finally, governments and central banks may launch monetary and fiscal stimulus packages to boost confidence, liquidity, and demand. This would mitigate the demand slack, bringing it back to the intermediate curve D_2 . This partial effect will be expansionary on production, and inflationary on prices, with a new equilibrium at point D.

What can we say about the likely net effect of these three partial effects (supply-side shock, demand-side shock, and stimulus policies)? First, the impact on inflation levels is ambiguous, with two inflationary (supply-side, stimulus policies) and one deflationary effect (demand bust), which furthermore may come in sequences – the supply-side shock being allegedly the initial impetus, with reactive income and policy responses. Second, by definition, a macroeconomic crisis will lower supply, demand, and incomes: counteracting stimulus policies should not trigger an outright *net expansion* in output. Still, we can analytically distinguish between two stylized scenarios. A pessimistic 1930s-style “lasting economic depression” would entail mass bankruptcies, unemployment, and an enduring global economic downturn – a scenario that finds support in some long-cycle theories of capitalist development (see Section 3.2). Conversely, under an optimistic “V-shaped recovery”, asset values, employment, and income growth would speedily and fully recover to pre-COVID-19 levels. While one of us is *ex ante* more inclined towards a pessimistic scenario (Wunder, 2020), we deliberately consider both stylized options here, recognizing that

greyscales between them are most likely to play out.

3.2. Financial markets and long economic cycles

Arguably, the potential macroeconomic severity of a pandemic crisis is conditioned not only by the size of direct and indirect costs, but also by timing. The world economy may currently be in a late-stage cycle of long-term waves in capitalist business cycles where crash potentials are high. Russian economist Nicolai Kondratieff analyzed in the 1920s 45–60-year-long waves, now labeled Kondratieff or K-waves (Korotayev and Tsirel, 2010). Arguably, our current phase corresponds to a Kondratieff Winter of economic depression (Fig. 3). The alternative Gann 90-year cycle had predicted that “the US stock market is due for another crash in 2020” – roughly 90 years after the 1929 crash and following an unprecedented period of continuous growth since WWII (Soos and David, 2017).

K-waves and other economic super-cycles are driven by underlying demographic, technological and land-speculation cycles, rising inequality, credit expansion, over-valued assets, and cycles of social mood driving collective behavior – the latter being summarized under the field of *socionomics* and Elliott wave concepts (Frost and Prechter Jr., 2005). Some underlying indicators are objectively quantifiable. For instance, global debt had reached more than triple the world’s annual GDP (Oguh and Tanzi, 2019), yet another 10% was added in 2020-Q1, to a staggering US\$258 trillion (Larson, 2020). As a result, the velocity of money, declining since 1998, has nosedived to unprecedented lows (FRED, 2021). Many European and American pension schemes will face solvency problems due to adverse demographics, insufficient savings, and low yields, and are now being further hit by irregular contributions during COVID-19 (Financial Times, 2020). Income inequality in most OECD countries stands at a five-decade high (OECD, 2011), which often coincides with market peaks.

Over-leveraged stock markets only survived the 2008 financial crisis

on bailouts and unprecedented steroids from successive central bank liquidity injections. Stock markets, the bellwethers of market economies, feature over-valued price-earnings ratios that since 1870 were only exceeded twice: prior to the 1929 crash and during the technology stock bubble around 2000 (Shiller, 2020). Never before has so much stock buying been financed through margin debt (EWI, 2021). Weirdly accelerating valuations also persist in other societal domains, as when ten soccer players have fetched 100–222 million EUR in transfers (Statista, 2020). All these phenomena have historically been observed prior to asset crashes. Curiously, the first stock-market bubble ever, the Dutch tulip mania and crash in the 1630s, also coincided with a pandemic (the ‘Black Death’ bubonic plague) (Goldgar, 2008).

3.3. Stimulus policies

Following the February/March 2020 lockdowns, stock markets plummeted, and unemployment soared. Governments in OECD countries responded with concerted economic stimulus packages. Between central bank liquidity injections and guarantees (more than half of the total), loans, value transfers and equity investments, the first two months of stimulus already totaled US\$10 trillion (Cassim et al., 2020). Fig. 4 shows that this initial stimulus corresponded to GDP shares ranging from 12% in the USA to 33% in Germany. Even for the largest emerging economies, stimulus was notable: India 10%, South Africa 8.6%, and Brazil 5.5%. European GDP equivalents for various countries dwarfed those after the 2008 financial crisis by a factor of ten. The European total (US\$4 trillion) was also in real terms 30 times larger than post-WWII Marshall Plan transfers (Cassim et al., 2020:p.2). The Marshall Plan had during 1948–51 accounted for barely 3% of recipient countries’ GDP (DeLong and Eichengren, 1993). Notably, this initial post-COVID stimulus has been followed by other large subsequent packages. In sum, we see a historically unprecedented experiment in shock therapy-style expansionary economic policies.

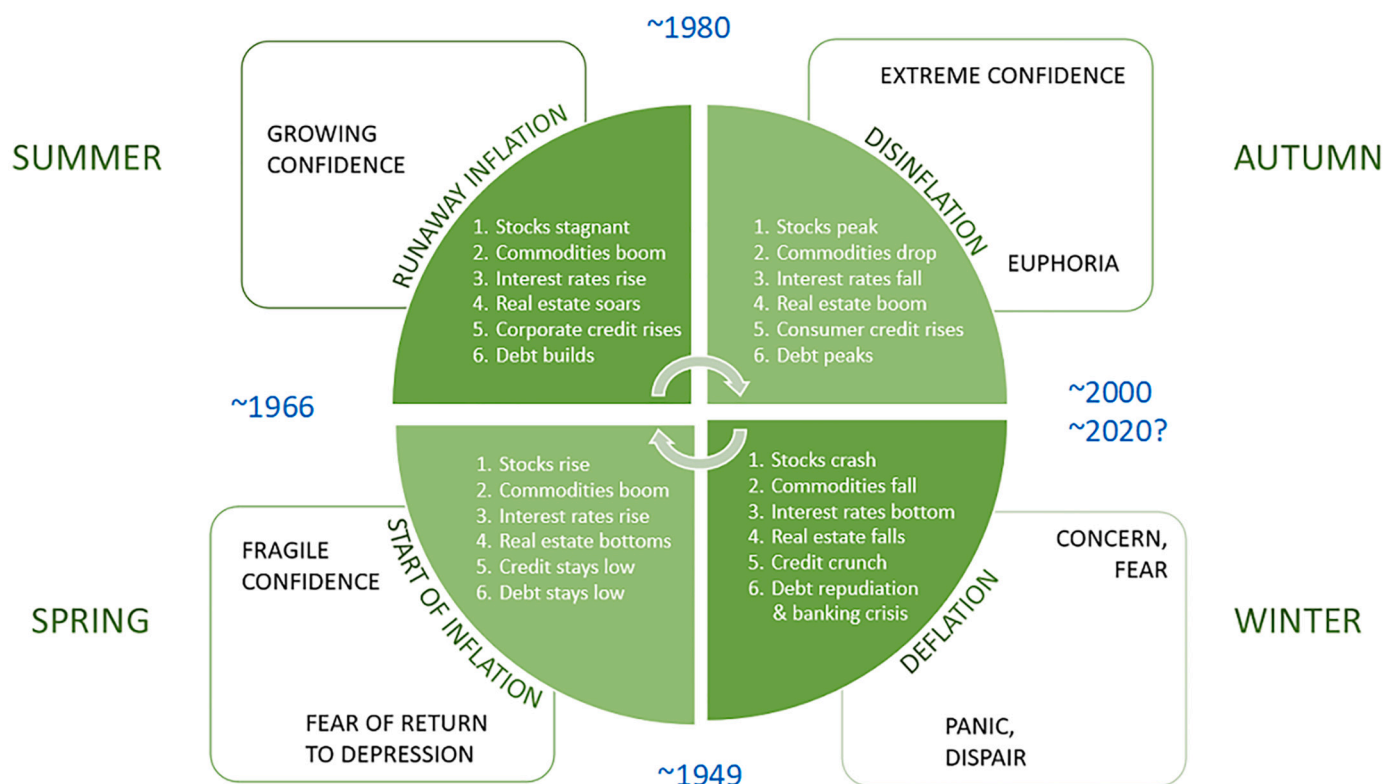
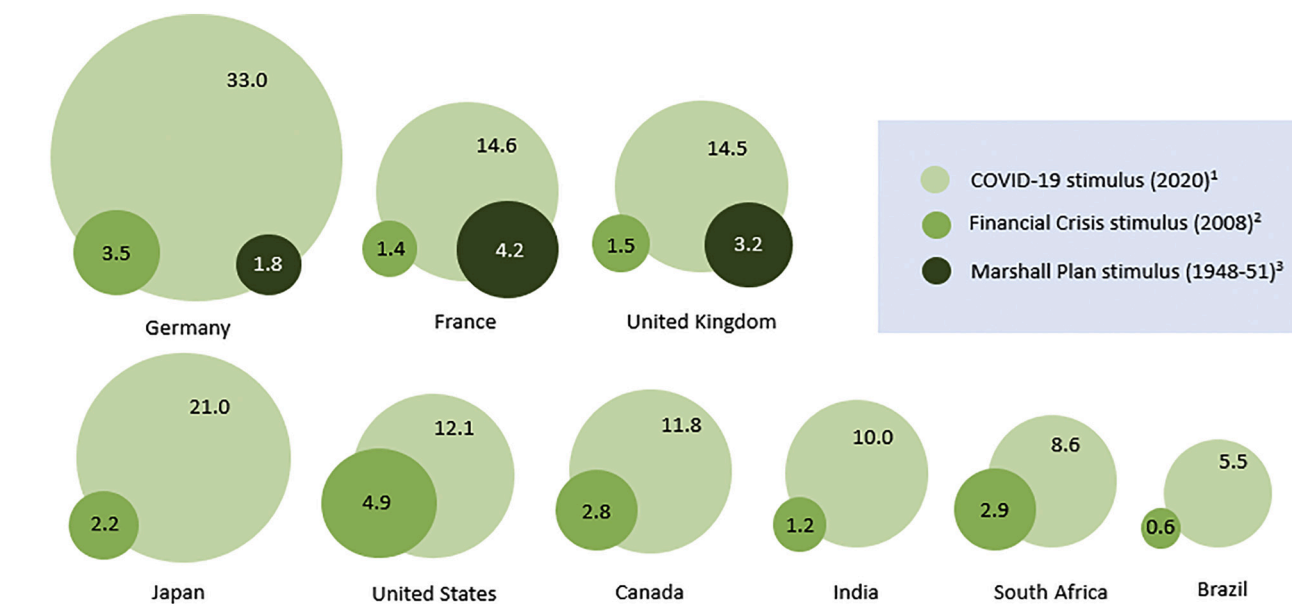


Fig. 3. Long-term Kondratieff cycles in capitalist development.

Source: Own preparation, inspired from: <http://www.ftense.com/2012/08/american-winter-understanding-natural.html>



Sources:

¹ Cassim et al. (2020:3), using 2019 as GDP base year; IMF and IHS Markit data.

² Cassim et al. (2020:3), using 2008 as GDP base year; various IMF data sources 2008-10.

³ De Long and Eichengren (1993), Maddison (2001), using 1950 as GDP base year.

Fig. 4. Aggregate stimulus payments as a share in GDP: economic crises compared.

3.4. Economic recovery outlook

The economic history of past epidemics and pandemics may give us a clue about typical recovery paths. Twelve major events with 100,000+ deaths since the 14th century were found to generally show significant macroeconomic after-effects persisting for about four decades, with real rates of assets return underperforming historic trends (Jordà et al., 2020). These epidemics typically induced labor scarcity and increased precautionary savings at the expense of consumption. However, COVID-19 affected the elderly disproportionately, taking a lower death toll on the world's productive labor force than e.g. the Spanish Flu did a century ago. Still, we should expect macroeconomic aftereffects to make lasting waves throughout the world economy.

A current reality check (end-May 2021) shows that the massive stimulus has helped completing a V-shaped recovery in some countries and indicators, in others not. The IMF's semi-annual World Economic Outlook found in its latest (January 2021) update a global GDP decline by 3.5% in 2020 – much less than the 4.6% contraction predicted in May 2020 (Fitch, 2020). Among subgroups, only China has reconquered its 2019 projected growth path; other advanced economies, as well as emerging markets and developing economies, are still struggling to regain their end-2019 GDP levels (International Monetary Fund (IMF), 2021: Fig. 1). The European Union saw a 7% GDP contraction in 2020, but IMF simulations show that stimulus policies have saved one quarter of corporate value-added and 15% of employment (Ebeke et al., 2021). Most stock markets have after April 2020 been optimistic: US technology stocks (Nasdaq) are exceeding pre-COVID levels by 50%+; British or Spanish indices have recovered only three fourths of their pre-slump level. We thus see a highly uneven recovery, where especially the financial markets, rationally or irrationally, are trying to front-run the real economy.

3.5. Forests in the North

Forestry operations across Europe have been considered high priority, so that little lockdown supply-side shocks have been experienced; similarly, management activities and wildfire controls have been

continued, though with less personnel (Stoof et al., 2020). In Spain, for instance, timber production has only suffered from slacking exports (CIC Construcción, 2020). In turn, more labor-intensive, and especially informal activities, such as mushroom harvesting, have been prohibited under the Spanish lockdown (Calero, 2020). Forestry employment was compromised, especially where relying on migrant workers (International Labour Organization (ILO), 2020). Forest-owner trends are variable; a survey showed that small forest owners in Finland spent more working time in their forest during COVID-19, while their Portuguese counterparts spent less (Hardcastle and Zabel, 2021). Recreational forest uses have expanded during COVID-19; one German peri-urban forest saw a doubling of visitors (Derks et al., 2020).

Lumber prices had hiked by one-third between 2016 and 2018, and again August 2019 to January 2020. The upward price trend is being linked to climate change impacts on supplies, through wildfires and large-scale bark beetle attacks (Meyer, 2021). Yet, demand effects have dominated short-run fluctuations: less construction traditionally reduces demand for, and diminishes prices of timber, as seen in the USA (Prestemon et al., 2018), China (Zhang et al., 2015) and Japan (Hansen and Luppold, 1992). With this backdrop, US lumber prices were spectacularly halved during March 2020, as construction slumped with COVID-19 lockdowns. But markets not only recovered with government stimulus; they also boomed with demand from homeowners adapting their home offices and urban dwellers fleeing dense cities into the suburbs. Simultaneously, US sawmills were affected by shutdown-induced labor shortages, causing inflationary supply-shock effects (McClellan, 2020). From the March 2020 low to April 2021, lumber prices thus skyrocketed sevenfold, being labeled “the hottest commodity on the planet” (Meyer, 2021). As we write, lumber prices have pulled back by 25% during one single month (see Section 4). Also noteworthy is that sawn log prices, i.e. prices paid to producers for their raw timber, have lagged far behind this spectacular boom, indicating that supply-side shortages at the retail end, combined with speculative forces, have driven the lumber boom, and probably sawmill windfall profits, into current excesses (McClellan, 2020).

As for other wood products, lockdowns increased demand for packaging material and pallets, while print-quality paper demand weakened

(Hardcastle and Zabel, 2021). The prices of pulp and paper also slumped in direct response to lockdowns, and only hesitantly recovered their pre-COVID-19 level (see Section 4).

4. North-South economic ties

4.1. Commodity prices

A prime linkage between the economies in the North and South is imports and exports of goods. Expansion of agricultural commodities has been a key driver of tropical deforestation, especially the so-called ‘big four’: cattle, oil palm, soy, and wood products (Pendrill et al., 2019; Nolte et al., 2017). World-market commodity prices are thus key incentives for land- and forest-use changes. However, direct drivers differ across deforestation frontiers; for instance, subsistence agriculture remains dominant in Africa. In this millennium, smallholder cash crops have gained deforestation momentum (Pacheco et al., 2021). The influence of commercial agriculture has been rising since 2013, with two thirds of land cleared illegally, though the share of domestic markets has expanded most rapidly (Dummet et al., 2021).

Fig. 5 contextualizes recent global market-price development (indexed January 2016 = 100) for eight agricultural commodities of our particular interest: six that directly compete for land use with tropical forests, and two key staple crops (wheat and rice) for comparison. For reference, we marked the main COVID-19 crisis onset by a vertical before-after division line (February 2020), although epidemic timing varied across countries (Section 2).

Most agricultural commodities experienced already strong fluctuations since 2016 but had during the last half of 2019 recorded overall favorable price trends; coffee and palm oil had outright booms, which were already ending before COVID-19. Especially sugar, live cattle and palm oil prices then faced strong post-COVID declines until end-April 2020. All agricultural commodities but rice⁴ faced declining prices between end-January and end-May (Baffes and Nagle, 2020). Hereafter, price paths have strongly diverged: wheat, soybeans and especially palm oil continued their ascending trend way beyond pre-COVID levels; rice, coffee, and sugar recuperated just about these levels, while cattle and cocoa stayed behind.

The pattern thus confirms deflationary forces from the COVID-19 demand reaction (Section 4), but following stimulus responses these were offset, and perhaps mingled with supply-side rigidities, including during the economies’ reopening, causing some of the widely expected inflationary pressures to materialize with a delay (Debgupta, 2020; Saba, 2020). Multi-sourced global food value chains reacted flexibly, compared to the past (The Economist, 2020); for key staples (rice, wheat, maize), global stock-to-use ratios were higher than during the 2008 financial crisis (Glauber et al., 2020). The outlook for most food markets thus remained favorable (FAO, 2020).

Still, many local commodity value chains were impaired, markets cleared imperfectly, and prices developed more heterogeneously than our above world-market price picture depicts. For instance, numerous meat-processing factories in Europe and the US had to close due to high worker infection rates, thus affecting prices and availability of output. Analysis of trade data shows the US supply shortfall stimulated Brazilian beef exports to grow by 50%; 12% of such frozen beef imports came from Amazon slaughterhouses in high-deforestation risk zones (Zu Ermgassen, 2021). Conversely, export markets for certain perishable (e.g. flowers⁵) and/or highly labor-demanding commodities (e.g. vegetables) suffered profound supply-side and trade disruptions. In some cases,

⁴ Rice prices rose due to both bad weather and COVID-19 stimulated export bans (see below).

⁵ The crashing US\$8.5 billion global flower trade showcases a perishable product, but mostly due to social distancing measures in the North reducing the demand (Bloomberg Businessweek 2020).

COVID-19 thus induced more commodity trade from the tropics, in others less.

Fig. 6 shows various non-agricultural commodity prices of tropical relevance. We have already commented on the timber hyper-boom, and more modest price recovery for pulp & paper. Gold prices recorded a persistent upward trend since 2016 (+69%), little affected by the COVID-19 commodity bust; gold mining has over the last decades become a key driver for forest loss (Alvarez-Berríos and Aide, 2015). Finally, petroleum prices collapsed under the transport freeze and general demand slack: US oil futures prices famously declined from US\$54 into deep negative territory in late April, but recuperated 2019 levels in early 2021.

On aggregate, we thus see a differentiated picture with some supply-side COVID-19 impacts. Upon post-lockdown reopening, more supply bottlenecks appeared than during the February 2020 shock, as structural changes in demand played out – the timber bonanza being an extreme example. Overall, demand-side COVID-19 effects were clearly in the driver’s seat: first deflationary bust, then post-stimulus inflationary dynamics. The S&P GSCI⁶ index, consisting of 24 weighted commodities, serves us as benchmark (Fig. 6). From index = 160 in January 2002, it rallied to 896 in July 2008, only to crash to 305 with the financial crisis in 2009. A renewed rally to 785 (May 2011) was followed by a downward move towards the lockdown 219 low (April 2020), but with a strong recovery to 506 since (mid-May 2021). Hence, COVID-19 marked just one phase among many strong price fluctuation legs around a downward trend during this Millennium.

4.2. Trade policies and globalization

The transmission of trade incentives between the global North and South is mediated also by trade policies, at both the sending and receiving end. The post-WWII period has been characterized by progressive trade liberalization and globalization feeding into a pro-growth strategy, but this model ran into resistance in recent years. COVID-19 is reinforcing anti-globalization sentiments: virus spread is linked to high global mobility and international interconnectedness; less globalization is thus naturally seen as limiting pandemic risks.

Profitability-optimized global value chains have also been proved vulnerable by COVID-19, thus potentially compromising food, medicine, and other basic-needs security, as well as strategic industries (e.g. automobiles) being effectively paralyzed by supply-chain disruptions. Full-scale globalization can thus come to be at odds with national security concerns, and steps are emerging to address it. For instance, Japan has earmarked ¥243.5 billion in subsidies to Japanese manufacturers for shifting China-outsourced strategic production home to Japan (Reynolds and Urabe, 2020). By May 2020, 15 countries had introduced binding export restrictions on food items, with especially those for large producers of rice (Vietnam) and wheat (Kazakhstan) inflating global prices (Laborde et al., 2020). On the import side, China is increasing inventories of corn and soybeans (Gu and Daly, 2020). A widespread global protectionist surge could render ‘beggar-thy-neighbor’ policies the norm, curbing global economic growth moving forward, and potentially restricting also trade in tropical commodities.

4.3. International tourism

A showcase victim of the COVID-19 crisis is the tourism sector. In 2019, tourism worldwide generated 10.3% of global GDP, having for the ninth consecutive year grown quicker (3.5%) than the global economy (2.5%). The World Tourism Organization (UNWTO) estimated that international tourism generated some US\$1.7 trillion in 2018. France,

⁶ Standard and Poor’s Goldman-Sachs Commodity Index (<https://us.spindex.com/indices/commodities/sp-gsci>); values were obtained from [TradingView.com](https://www.tradingview.com).

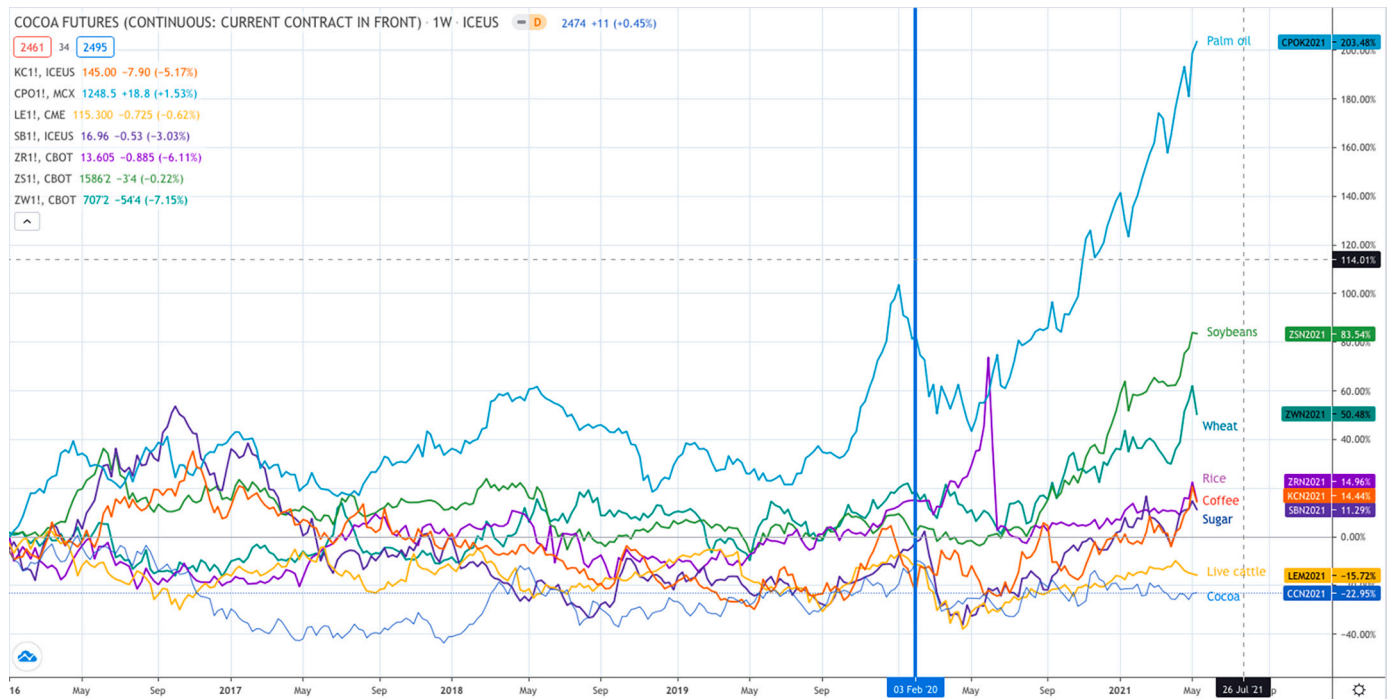


Fig. 5. Agricultural commodities futures prices. Jan 2016 = index 100 Source: Generated in Tradingview.

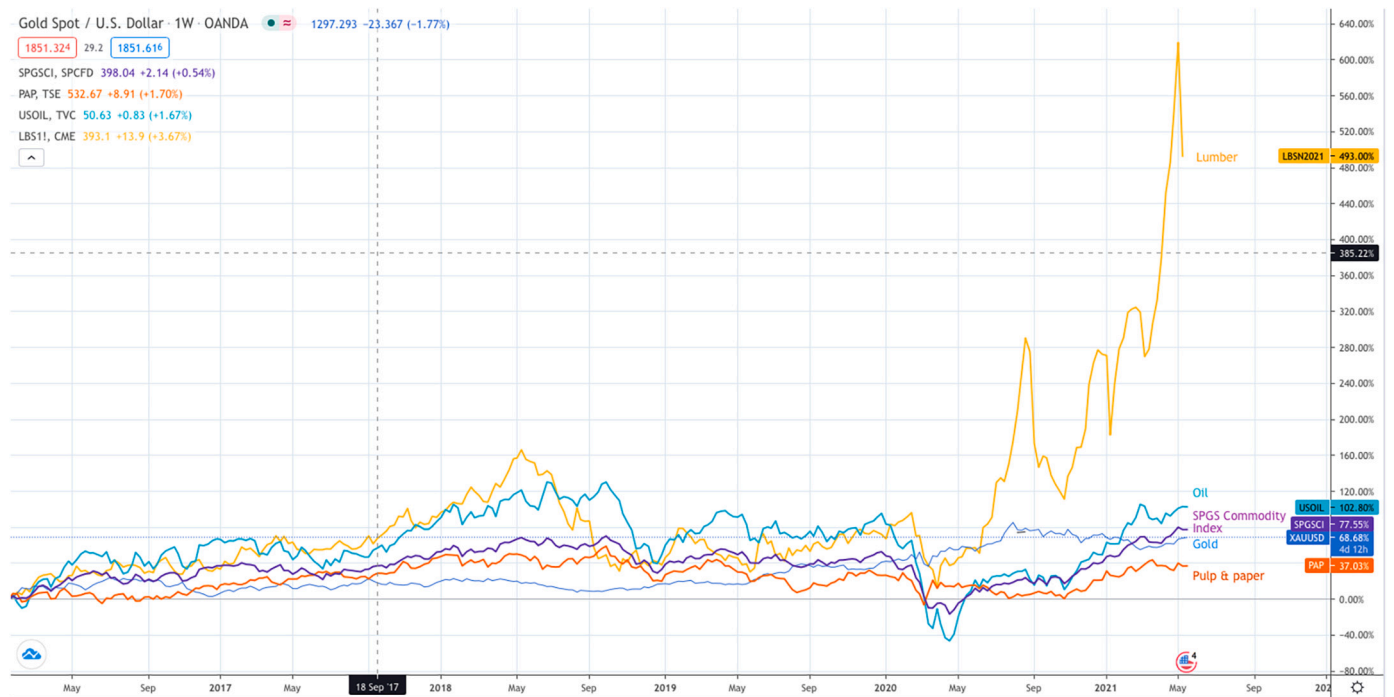


Fig. 6. Gold, oil, and forest product futures prices. Jan 2016 = index 100 Source: Generated in Tradingview. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Spain, and USA were the top-visited destinations, yet South Asia was fastest-growing, with a 19% increase in tourist arrivals (World Tourism Organization, 2019). Africa only received 5% of all arrivals, but highly depends on tourism’s foreign exchange revenues. In the Seychelles, tourism generates more than 60% of GDP; in Namibia 19% of all employment is directly or indirectly related to tourism. Ten million Africans work directly, and some 14 million indirectly in tourism

(Taylor, 2020).

By 4 May 2020, a 95% reduction in passenger air traffic had occurred (IATA, 2020). Most tourist destinations came under lockdown, since over 90% of the world’s population live in countries with international travel & LSSD restrictions (Gössling et al., 2020). The World Bank estimated that around 50 million jobs in the global travel and tourism sector were at risk (Zeufack et al., 2020: 32). We can only guess about

economic losses. For comparison, a 2009 five-month swine flu epidemic cost Mexico about one million overseas visitors, losing around US\$2.8 billion (Rassy and Smith, 2013). The tourism suspension has dire implications for both urban-based tour operators and rural communities residing nearby tourist destinations. Ecotourism had in Southern and Eastern Africa become centerstage to market-based conservation (Büscher and Fletcher, 2020): local jobs and purchased services created new livelihoods options (Harilal and Maloney Tichaawa, 2018). Currently, more social conflict around natural resources looks likely, possibly also increasing pressures on forests.

4.4. Capital flows and exchange rates

During global economic crises, the Global South usually suffers net capital outflows, as carry trades (seeking higher interest rates) and other “risk-on” transactions are being reversed. The COVID-19 led force of capital outflows in February/March 2020 was unprecedented: around US\$100 billion (0.4% of GDP), double that faced in 2008 (Adrian and Natalucci, 2020). In addition, remittances by South-North migrants back to their home countries may come to fall by another US\$110 billion, as many migrants have lost their jobs, especially in the service sectors (Bisong et al., 2020). Finally, COVID-19 also reduced foreign direct investment (FDI) flows by an estimated 30–40% during 2020–2021, contributing further to foreign exchange shortages in the Global South (UNCTAD, 2020). Notably, the Group of 20 (G20) countries has called for a Debt Service Suspension Initiative, and the IMF for an extraordinary allocation of Special Drawing Rights (SDR), which would alleviate the situation.

Overall, it is thus no surprise to see this foreign-exchange scarcity reflected in strong currency devaluations of five major tropical countries in early 2020, after relatively stable rates in the second semester of 2019 (Fig. 7). The Brazilian Real reached 55% devaluation vis-à-vis the US\$ in May 2020, before recently correcting back to 30% loss. The Mexican Peso was down 33%, recuperating now to 8% loss. The Congolese Franc devalued about 10% vis-à-vis the EUR, its main trading partner being Europe. The two southeast Asian currencies, the Indonesian Rupiah and the Malaysian Ringgit, both ended up with a modest 5–6% devaluation to the US\$, though the Rupiah in April 2020 had been down by 20%.

Where many commodity prices thus exceeded pre-COVID levels, exchange rates stayed more devalued – reflecting that other capital net outflows did not reverse at the speed of commodity markets. These devaluations thus *ceteris paribus* increased incentives to export land-using and/or forest-displacing commodities. On the other hand, the large volatility of both exchange-rate and price moves acts also as a partial disincentive for exporters to invest.

5. Likely economic effects in the South

5.1. Economic outlook

Many countries in the GG=Global South made it comparatively well through the financial crisis of 2008; the outlook for the COVID-19 crisis is harsher, though also more uneven. End-May 2020, following the lockdowns, emerging markets had been projected to shrink by –4.5% in 2020 (Fitch, 2020). Ultimately though, GDP in emerging and middle-income economies contracted in 2020 by just 2.4%, while low-income developing countries stayed flat (0.0%) – the former being clearly more trade-exposed and labor-mobile, with higher infection rates. Shrinking 7.0%, Latin America was worst affected, whereas Sub-Saharan Africa (–1.9%) and Asia (–1.0%) were comparatively less hit, though with exceptions such as South Africa (–7%) and India (–8.0%) (International Monetary Fund (IMF), 2021). Still, the Global South faces its strongest post-WWII crisis.

In Africa, global demand effects have arrived long before COVID-19 infections (e.g. through the tourism standstill). Its employment contraction was larger than that of GDP (Selassie and Tiffin, 2021), in

what is shaping up to be the continent’s worst crisis in decades (Zeufack et al., 2020). Africa’s COVID-19 infection rates may also persist longer, in part due to slower vaccination. Indeed, all three subregions face crises that are harder to reverse than in the global north, due to their greater previous indebtedness, lower savings and reduced borrowing capacity to finance compensatory economic stimulus (Han et al., 2021; Selassie and Tiffin, 2021).

5.2. Domestic crisis adjustments

From previous economic crises in the Global South, e.g. during the 1980/90s, we know approximately what internal economic adjustments we might expect (e.g. Little et al., 1993):

1. Bust in foreign exchange earnings from reduced trade in goods, services (incl. tourism), remittances, and net capital outflows;
2. Less private investment due to credit/liquidity bust and greater uncertainty;
3. Rising poverty and changing domestic consumption patterns;
4. Reduced government taxes and royalties, broadly curbing government current spending (public employment, health system, subsidies, etc.);
5. Reduced government investments (e.g. in new infrastructure);
6. Deteriorating governance (incl. environmental protection efforts);
7. Rise of informal economy (low costs, no taxes), illegality, subsistence focus;
8. Reduced urban labor absorption (e.g. in construction) and urbanization, or outright net return migration; lower internal remittances.

Factors 1) and 2) express the new reality vis-à-vis *external balances*, whereas 3) is the likely consequence for *private investors and consumers*, respectively. Then, 4), 5) and 6) mirror the generally *reduced capacity of government* to actively intervene in the economy. Finally, 7) and 8) mark *structural changes* across sectors to better cope with the crisis and falling incomes. Notably, the weight of these factors will differ across exported commodities: for agricultural commodities and timber, the direct market incentives for land expansion and wood extraction (1–3) will dominate; for oil and mineral commodities, direct deforestation effects are often smaller: the economic rent element (pure profits net of all costs) is larger, and all depends on what rent owners (typically, governments) decide to spend them on (Wunder, 2003). We will return to these factors below, discussing their forest implications.

6. Land use and forest effects

6.1. Drivers of forest change

An ample corpus of literature on the causes of deforestation in the Global South highlights a series of extra-sectoral factors, especially driving agricultural land demand for converting forests to alternative uses: these are typically forward-looking investment decisions driven by their profitability. Forests are disappearing mostly due to a growing appetite for land, rather than for trees (Kaimowitz and Angelsen, 1998; Angelsen and Kaimowitz, 1999). In turn, forest degradation, e.g. through the over-harvesting of precious timbers or fuelwood, is typically an extractive, one-off activity that depends little on secure land tenure or a predictable time horizon for investment (Wunder, 2005). Tandems, or even clusters of forces and motives often come together in triggering deforestation and/or forest degradation (Lambin et al., 2001; Geist and Lambin, 2002).

In their meta-study on deforestation drivers, Busch and Ferretti-Gallon (2017) list multiple factors (see Fig. 8) that have consistently been associated with low deforestation (white-colored bars), high deforestation (black-colored bars), or no consistent association (shaded bars) in the literature. First, some spatial-contextual variables are known to effectively protect forests: high, inaccessible, wet, steeply sloped

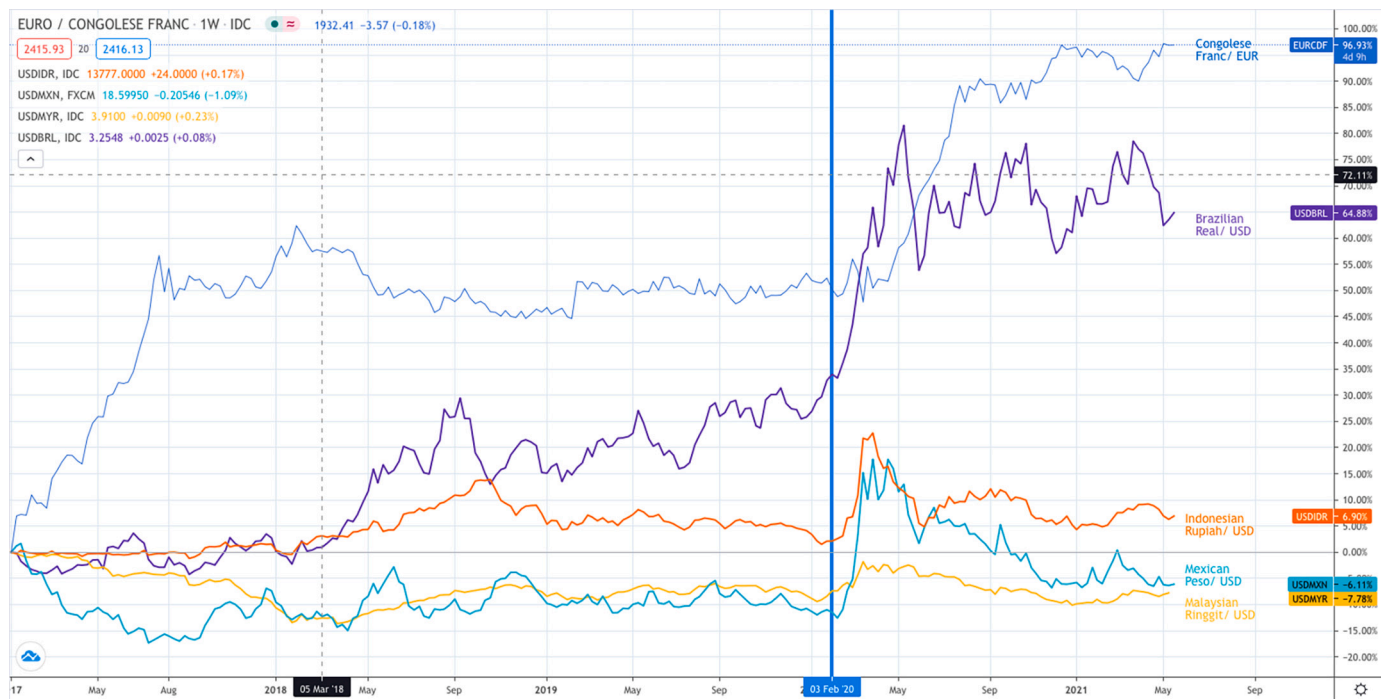


Fig. 7. Exchange rates in major tropical countries. Jan. 2017 = index 100. Source: Generated in Tradingview.

lands, with poor soils. Obviously, these site-specific, fixed characteristics offer little leverage for change in a pandemic setting. We would be more interested in deforestation drivers that were to change during adjustment to an economic crisis. Say, the presence of indigenous peoples and low population density both correlate with low deforestation; hence a

government-financed program resettling landless farmers into indigenous territories would be expected to fuel deforestation – and the crisis-driven loss of government funds leading this program to be abandoned would de facto become an (unintentional) forest-protective crisis effect.

Among the potentially leveraging factors in Fig. 8, we can distinguish

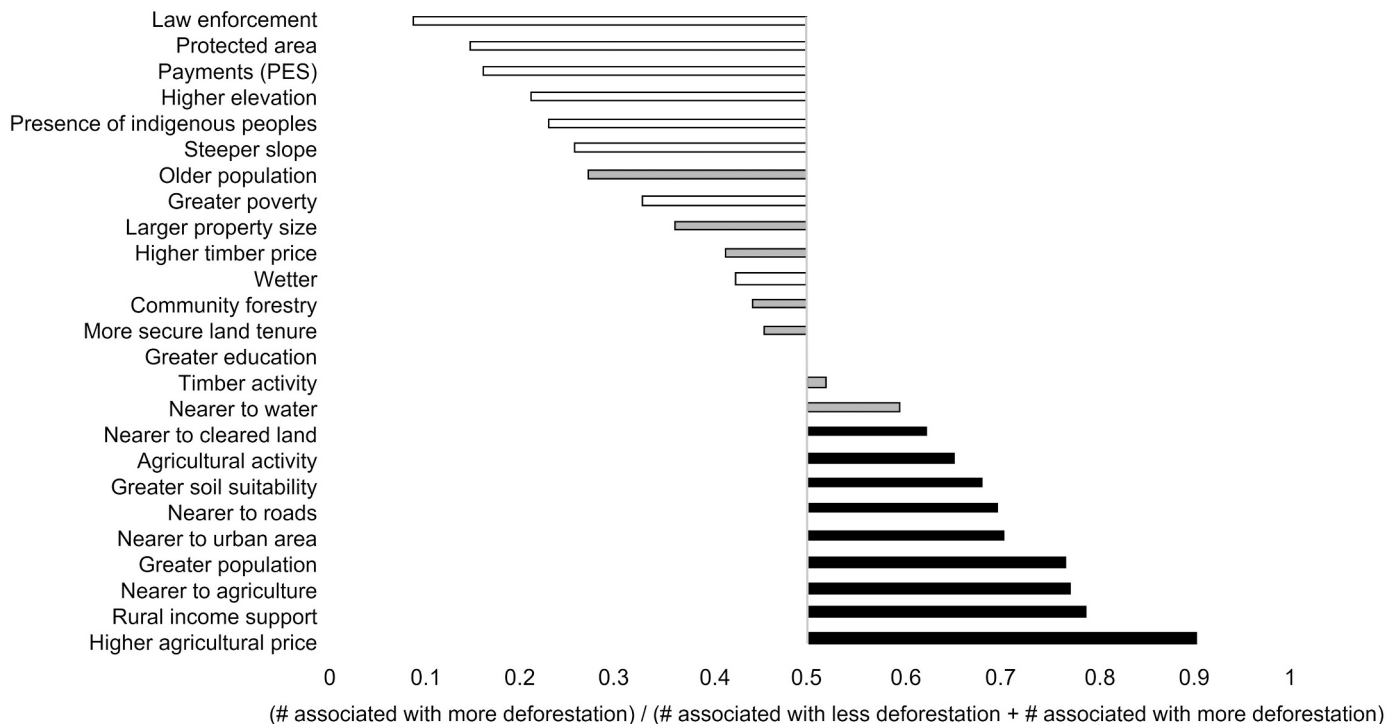


Fig. 8. Meta-study of deforestation drivers: the consistency of correlation.

Note: Consistency of association of driver variable with more or less deforestation at regression level. Bar colors: consistently associated with less deforestation (white), more deforestation (black), or inconsistent (grey) across 592 statistical analyses.

Source: Busch and Ferretti-Gallon (2017), Appendix A.

three types:

- i. direct *forest-targeted interventions*, such as pro-forest incentives (payments for environmental services) or disincentives (law enforcement, protected areas);
- ii. interventions promoting *alternative forest-converting land uses* (agricultural subsidies), building/improvement of roads, which are usually forest-threatening; and
- iii. joint *policy-market outcomes*, such as higher agricultural prices and (causally complex) higher poverty.

6.2. Past crisis impacts on forests

Most of the literature about the macroeconomics-crisis-forest nexus was written around the turn of the millennium, dealing with the issue either generically (Reed and Sheng, 1998; Shafik, 1994; Capistrano and Kiker, 1995) or relating to foreign debt (Kahn and McDonald, 1995) and structural adjustment policies (Reed, 1992; Reed, 1996; Cruz and Repetto, 1992; Kaimowitz et al., 1998; Seymour and Dubash, 2000), as well as commodity-led boom-bust patterns of tropical countries, such as Cameroon (Eba'a-Atyi, 1998; Mertens et al., 2000; Sunderlin et al., 2000a; Ndoye and Kaimowitz, 2000; Sunderlin and Pokam, 2002; Sayer et al., 2012), Ecuador (Wunder, 2000), Indonesia (Sunderlin et al., 2000b; Sunderlin et al., 2001), Suriname (Sizer and Rice, 1995), or a comparative sample of oil-exporting countries (Wunder, 2003; Wunder, 2005).

Which crisis events in tropical countries can we potentially learn from? Beside the longer-lasting credit crunch and debt crisis in the 1980s and early 1990s, the global financial crisis of 2008 was a more recent, shorter-lasting event. Yet, it had only moderate impacts in the Global South, in large part because the Chinese economy proved robust in its recovery and commodity demand. Asia faced a financial crisis of its own in 1998/99 that had more regional flash-crash features of shorter duration. Finally, various commodity prices slumped jointly during 2014–16, which affected exporting developing countries.

What forest impacts could we thus expect from a prolonged crisis in the Global South, vis-à-vis the items listed above?

1. *Bust in commodity trade, tourism, remittances, and capital outflows*: Declining trade volumes would likely dominate here (unless exchange rate devaluation effects are large and sustained), reducing incentives to deforest new areas; conversely, unemployment from lost incomes may also generate pressures towards increased subsistence farming (Section 6.3).
2. *Less private investment*: If investors perceive the crisis to be mostly temporary, land grabbing and commodity investments would remain robust; e.g. after the 2008 financial crisis, deforestation did not slow down much. Still, fewer new mining projects in forests seem to occur, with less finance and reduced incentives to extract lower-priced minerals (Butler, 2015).
3. *Rising poverty and changing consumption patterns*: Rising poverty was flagged as an unambiguous deforestation-reducing factor in Busch and Ferretti-Gallon (2017), through reduced national economic activity in forested countries. In case-study reality, still many internally opposed factors are at play. Consumer savings-led cutbacks on protein-rich meat and dairy products (e.g. in Latin America) will reduce deforestation; the shift to more consumption of firewood and tuber subsistence crops (e.g. in Central Africa) may increase forest pressures (Wunder, 2003). Most deforested lands in Latin America end as pastures (e.g. Kaimowitz et al., 2004). Beef has high income elasticity, so its use will decline when incomes fall (Gallet, 2010), especially at the low-income end (Zhao et al., 2020). Expanding and changing domestic food consumption has been an underestimated deforestation trigger in recent years (Castro, 2020). Even small changes in larger-scale populations' income can thus matter for

domestic market-induced deforestation pressures (Alix-Garcia et al., 2013).

4. *Less government spending* (employment, subsidies, etc.): How this affects forests depends on how public budgets were spent before the crisis. If governments used to subsidize fuel costs, agricultural production, and resettlement of people into forested areas, then cutting these costs will come to protect forests (Wunder, 2003).
5. *Less government investment in new infrastructure*: Road construction through forests may be the single most important global deforestation driver (Laurance et al., 2014). Capital investments such as roads across the Global South are particularly crisis-sensitive (Carranza et al., 2011; Beuran et al., 2015), and it is harder to borrow externally for these projects. A few key road projects, abandoned due to COVID-19, could thus preserve ample forest areas.
6. *Deteriorating governance, including environmental protection*: Governments have fewer resources (and give lower priority) to environmental enforcement and protected area management. Since both factors were unambiguously forest-protective in meta-studies, their weakening is likely to have environmental costs (Butler, 2015).
7. *Rise of informal/subsistence economy*: More informal-sector, subsistence-oriented, and sometimes illegal production (e.g. illicit crops) provide less leverage for conservation market mechanisms (e.g. certification) (Butler, 2015). Loss of off-farm income reinforces the drive towards subsistence and forest loss (Araujo et al., 2019).
8. *Less rapid urbanization, or outright return migration*. Perhaps the strongest argument for crisis-led deforestation occurs if more of the population surplus stays in/returns to land-extensive slash-and-burn agriculture in systems with excessive rural population density (Sunderlin and Pokam, 2002). On the other hand, urban construction will decline under crisis, likely implying less forest degradation from timber extraction. Massive post-lockdown urban-rural return migration has been seen e.g. within India (minimum 6.3 million train travellers during May–June 2020), Indonesia, Peru and US-Mexico (Saxena et al., 2021).

As we can see from browsing this list of factors leading in opposite directions, it is hard to *a priori* determine the net impact of a severe economic crisis on forests: certainly, opposed scenarios are possible under different regional or temporal constellations. Ultimately, it is thus an empirical question which partial effects are dominating. Butler (2015) juxtaposed for the 2001–13 period three types of commodity prices (energy, agriculture, mineral) to tree-cover loss data from the University of Maryland (Fig. 9). From 2002 to 2012, commodity prices quintupled in a synchronized manner, but then levelled off and declined. Tree-cover loss followed along, including during the 2008/09 crisis, but then reduced already during the levelling-off process. This correlation confirms what the bulk of case studies, and the deforestation meta-study made us suspect: that forest-protecting effects from economic crisis may gain the upper hand through the commodity trade mechanisms – though probably with much variation over space and time.

6.3. Impacts on forests in the Global South

Compared to previous crises, this one is still in its early days, especially in terms of forest impacts: consolidated data are only available with a time lag. This section will first review early case studies based on preliminary data (short-run deforestation and fire alerts), and then look at the recently published Global Forest Watch (GFW) consolidated tree-cover data for 2020.

One early case study of the months after the COVID-19 lockdowns in Nepal found 4.5% fewer forest fire incidents, with 11% less fire radiative power, and 8% fewer fires in community forests, suggestively related to the government's mobility restrictions (Paudel, 2021). The opposite result is found by Amador-Jiménez et al. (2020) for Colombia, detecting a significant rise in forest fires in a comparison of the first semester of

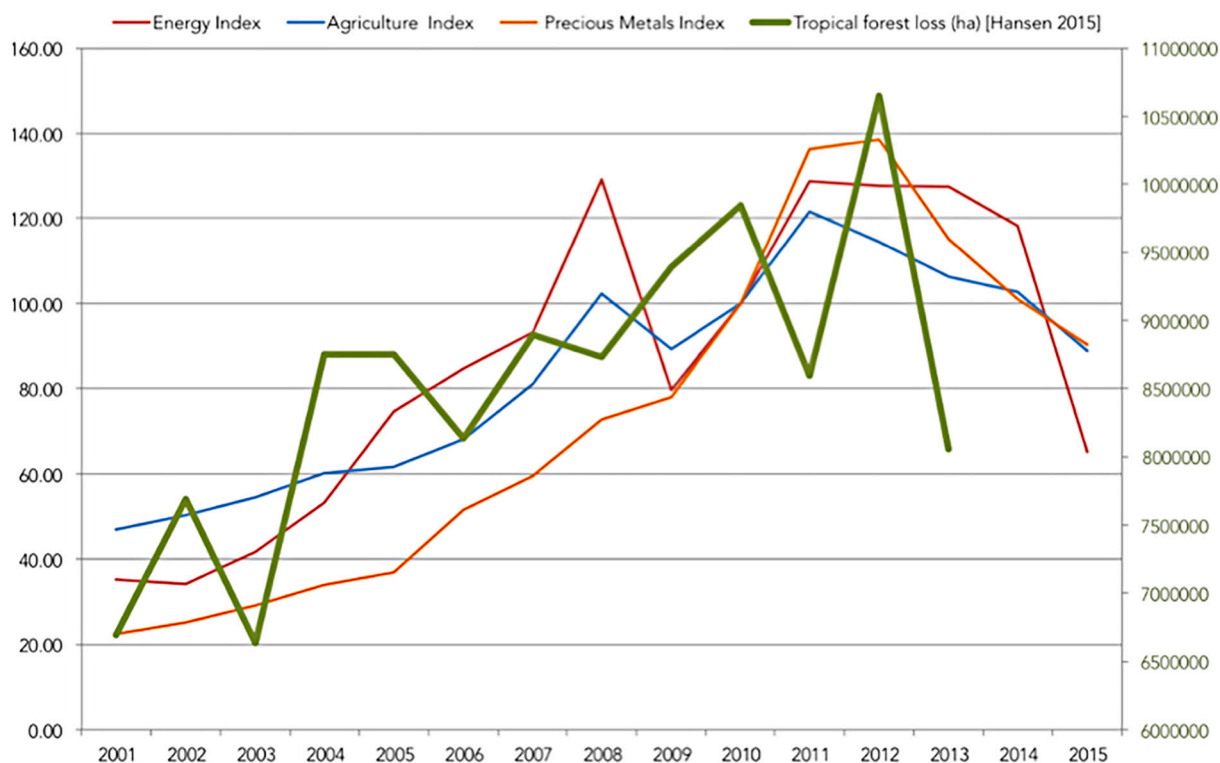


Fig. 9. Commodity prices vs. tropical tree-cover loss, 2001–13.

Source: Butler (2015)

2020 with those of 2012–19, explained by declining forest governance in regions where illicit crops have expanded. Income-losing producers in Colombia, e.g. farming and mining businesses, also lobbied for weakened environmental regulations (Rojas, 2020).

A pantropical study by WWF-Germany compared the Global Land Analysis and Discovery (GLAD) tropical forest data from GFW and the University of Maryland for February–June 2020 to the same months in 2016–2019: forest disturbance alerts rose in 2020 by a dramatic 77%, which the authors explained by an accelerated loss of forest governance and increased land grabbing during government lockdowns (Winter, 2020). For the first post-lockdown months, Brancalion et al. (2020) also found huge GLAD increases of 63%, 136%, and 63% in the Americas, Africa, and Asia-Pacific, respectively. The peak in GLAD alerts was widely noted and causally combined with circumstantial site-specific reports (Gross et al., 2020; Fair, 2020): any forest effects from reductions in economic activity would have been vastly outsized by a strong decline in forest monitoring and government enforcement, such as lockdowns constraining environmental police from patrolling in the field. As a Brazilian slogan has conveniently put it: “Land grabbers don’t do home office” (Sudré, 2020).

The general problem with these studies’ reasoning is timing: many tropical countries had not yet adopted lockdown measures when registering higher GLAD alerts; in fact, countries with the largest rise in the February/March deforestation alerts, such as Colombia or Thailand, only experienced lockdowns by end-March (28/3, and 25/3, respectively – Wikipedia, 2020). This mismatch in timing effectively invalidates any lockdown-attributable explanation. Saavedra (2020) looked closer into this for 70 tropical countries: during January–July, there were some 150,000 more deforestation alerts in 2020 than in 2019, but this divergence started in January, i.e. before the global pandemic. Using country-specific lockdown dates and difference-in-difference analysis, he finds generally no statistically significant difference between pre- and post-lockdown deforestation alerts. Still, for some important forest countries (Brazil, Mexico), post-lockdown alerts did rise strongly.

Alternative explanations for the large rise in GLAD alerts thus have to be sought. A simple one would be that the alerts data are inadequate for intertemporal comparisons. As GFW explicitly warns: “We do not recommend using the GLAD alerts for global or regional trend assessment due to limitations in the alerts, including the six-month long confirmation process, lag times in detection due to cloud cover and inaccuracies in alert areas” (Weisse and Pickens, 2020:p.9). Hence, GLAD alert data can quickly point to the “where, possibly?” question, but not really to “how much, for certain?”

For trend assessment, GFW refers instead to its annual tree cover loss data, which have just been published for 2020. These find 12.2 million hectares of tropical tree-cover loss for 2020, or 12% more than 2019: a small change (Weisse and Goldman, 2021). Also, given data insecurities, they recommend for trend analysis to focus on a three-year moving data average, which with the large 2016–18 decline was still *dropping* in 2020. In other words, registered changes in forest loss throughout 2020 were globally insignificant, meaning also that the sensational headlines from the GLAD alert-based studies had been precipitated.

That said, country-specific stories clearly differ. Fig. 10 shows that, among the three largest tropical forest countries, Brazil and DRC registered a slight increase in tree-cover loss (at quite elevated levels already), while Indonesia continued the decrease from recent years. Two of us analyzed in greater detail the land-use linkages in Brazil, Indonesia, and Mexico (Kaimowitz and Wunder, 2021). A main comparative conclusion, fully consistent with the GFW 2020 data, was that COVID-19 did not decisively change these countries’ respective pre-existing trends: accelerating deforestation in Brazil, continuously high in Mexico, and decelerating forest loss in Indonesia all continued unabatedly in 2020.

In Brazil, severely hit by COVID-19, illegal land occupation was booming, but the Bolsonaro government had already legally facilitated land grabbing before COVID-19 (Brito et al., 2019), and deforestation figures were already for months higher than during the four previous years (INPE, 2020). Still, COVID-19 provided a convenient political excuse to push forward an agribusiness-focused agenda of land expansion. As mentioned, Brazilian (and Amazonian) beef exports directly

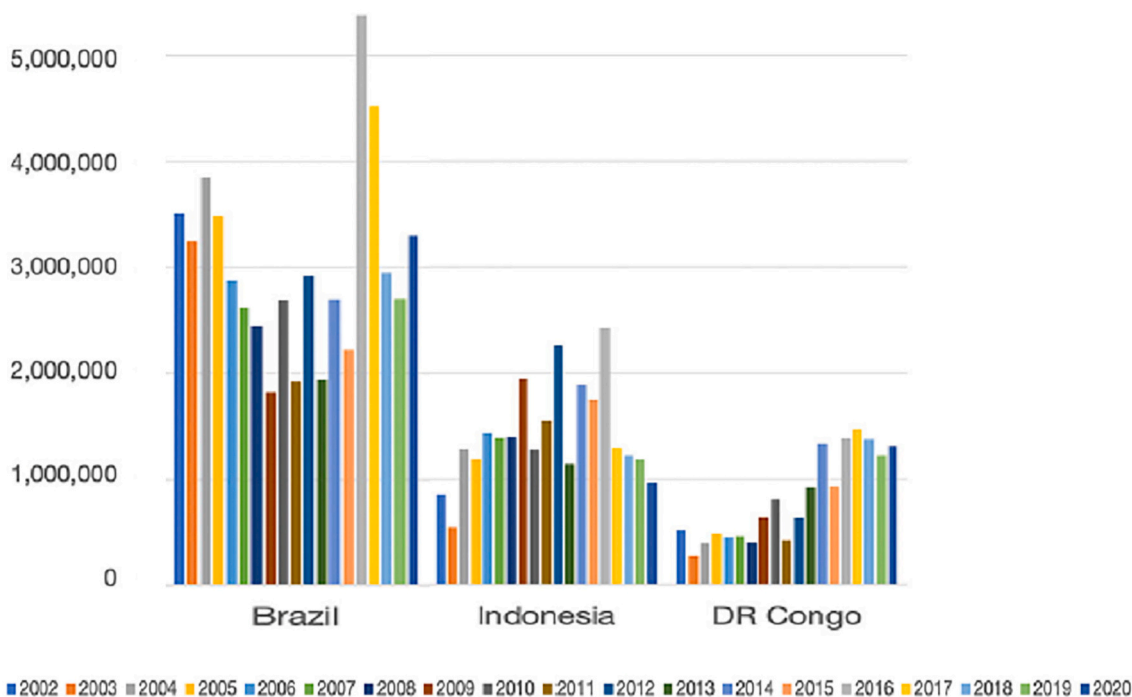


Fig. 10. Tree-cover loss data for Brazil, Indonesia, and Democratic Republic of Congo 2002–20.

Source: Butler (2021), Global Forest Watch & University of Maryland Creative Commons Attribution-NoDerivatives 4.0 International License.

substituted for supply shortfalls in the USA (Zu Ermgassen, 2021). Economic stimulus measures equaled a high 5% of GDP, cushioning the fall in domestic food demand (cf. Fig. 4). While tree-cover loss increased, it is still far from the recent peak loss in 2016/17. A report on COVID-19 and Brazil's greenhouse gas emissions thus concluded that the overall impact of the Coronavirus on land-use change and deforestation remains ambiguous (Azevedo, 2020).

Mexico, hit even harder by COVID-19 than Brazil, acted more fiscally conservative, and thus suffered more economic hardship and declining domestic markets. Rising exports of beef, avocado, and pork (linked to soybean-fueled deforestation), however, together with currency devaluation, increased some land-use pressures throughout 2020. Moreover, a strong community forestry sector suffered severe economic decline, debilitating a forest-protecting factor. Again, for all of these factors, COVID-19 came to go hand in hand with pre-existing trends (Kaimowitz and Wunder, 2021). While tree-cover loss declined marginally from 2019 (327,438 ha) to 2020 (299,527 ha), the 2020 loss was still the second-highest in two decades (Mikaela Weisse, GFW, pers.comm., June 2021).

Indonesia has so far suffered fewer infections, deaths and 2020 GDP decline (1.5%) than Brazil and Mexico (Kaimowitz and Wunder, 2021: p.15). Indonesia holds 55% of global palm oil exports; expanding plantations have been closely linked to high palm oil prices, and to deforestation (Gaveau et al., 2021). Still, around 40% of production was used for biodiesel in 2019, which, with the dramatic 2020 bust in petroleum prices, suffered to compete. This also affected coal mining, a recent source of deforestation (Kaimowitz and Wunder, 2021). Forest product prices, such as for pulp & paper, also suffered initially. Indonesia issued a decree in end-May 2020 to scrap timber licensing requirements, putting into jeopardy its EU Voluntary Partnership Agreement, though partially backtracking since (Jong, 2020). Overall, the basket of Indonesia's main forest-related and forest-competing commodities thus faced less favorable price trends than Mexico and Brazil. Together with successful policies – a temporary moratorium on new oil palm licenses, a permanent one on primary forest and peatlands conversion – this may explain why Indonesia managed to reduce tree-cover loss for the fifth consecutive year since its record-high of 2016

(Weisse and Goldman, 2021).

7. Conclusions and discussion

7.1. Three crisis effects

COVID-19 has been called “a crisis like no other” (Georgieva, 2020), representing the largest challenge to the world economy since WWII. In the sections above, we have conceptually analyzed the linkages between COVID-19 and emerging forest impacts. Compared to one earlier conceptual effort (Branca et al., 2020), we have analytically laid open a greater complexity and diversity of economically conditioned impacts. In turn, in our recursive structure we have abstracted from feedback loops from deforestation to COVID-19. For instance, forest burning can worsen respiratory impacts of COVID-19. Notably, bushmeat extraction and loss of forest biodiversity have been flagged as drivers of zoonotic infections (Wolfe et al., 2005), including COVID-19 (United Nations Environment Programme (UNEP) and International Livestock Research Institute (ILRI), 2020), so that investments in avoiding future deforestation and wildlife trade could pay off for future epidemic prevention (Dobson et al., 2020). Yet, not only tropical deforestation, but also booming oil-palm plantations and temperate re- and afforestation may be associated with increased outbreaks of zoonotic and vector-borne diseases since 1990 (Morand and Lajaunie, 2021). Likewise, greenhouse gas emissions from forest loss contribute to climate change, as a systemic crisis ahead. Hence, some medium-term ‘backwards’ feedback loops towards our economic/anthropic systems can be quintessential for humanity's resilience.

We distinguished between three partial crisis-related, allegedly sequenced effects, many of which due to data lags we could only incipiently verify. First, this concerns the COVID-19 supply-side shock from illnesses and lockdowns, where production shortages inflate the prices of goods and services. Second, falling incomes and precautionary savings depress overall demand, exercising deflationary pressures. Third, government stimulus responses, through expansionary monetary and fiscal policies, would counteract the deflationary demand contraction so as to restore economic confidence.

Seeing these textbook crisis effects play out in the COVID-19 reality was not a story without surprises. Only scattered initial inflationary supply-side effects occurred, including in agriculture and forestry in the Global North: the deflationary forces of demand contraction and asset deflation were initially operating much more quickly, as signaled through financial markets. More supply-chain distortions occurred only later, when storage levels and port capacities became compromised. Demand-side contraction in the North overshot, including due to Europe's inability to adopt more cost-effective pandemic strategies.

Simultaneously to a rapid selloff in financial markets, a dramatic fall in commodity prices occurred February/March 2020. Longer-term business cycle features during a Kondratieff Winter, with ultra-high indebtedness and reduced consumer and investor confidence, had arguably already debilitated markets. This demand contraction also hit the Global South long before the Coronavirus proper spread. It was exacerbated by strong South-to-North capital outflows, reduced remissions from migrants, and a near-total freeze of the large international tourism business. Consequently, exchange rates vis-à-vis the US\$ and EUR devalued strongly in emerging and low-income economies alike.

However, from April 2020 going forward the third effect came into play: Northern governments and central banks coordinated massive fiscal and monetary stimulus responses, much larger in relative size than the post-WWII Marshall Plan or the bailouts of the 2008 financial crisis. Economic policy responses have constituted an unprecedented experiment in economic stimulus in the history of humankind. Stock markets partially or (more than) fully recovered, as did commodity prices, and the exchange rates of Southern currencies vis-à-vis the US\$ and EUR. We probably need to question our initial assumption that economic stimulus can only retrace part of the crisis-induced losses: in some markets, stimulus effects may have over-compensated pandemic losses.

In that sense, if the medicine makes the patient more excited than before the illness, is it still justified to talk about a crisis? With COVID-19 vaccines being rapidly disseminated, and lockdowns opening up successively, is the global economy thus out of the woods, and off to another decade of post-pandemic Roaring Twenties, as was the case after the Spanish Flu and WWI a century ago? We remain skeptical vis-à-vis structural Kondratieff-type cyclical weaknesses, e.g. sky-high debt levels, record-level income inequality, and bubblish stock market valuations. What will happen once the shock therapy doses of government stimulus are being phased out, artificially low/negative interest rates start hiking, and pandemically starved-out businesses increasingly fail? Is a deflationary bust needed before a genuinely lasting recovery can occur, so as to wipe out excessive debt and asset inflation? We will leave these tricky questions unanswered, but we have certainly so far seen an abnormal global crisis, which in its peculiar manifestations also has some new implications for forests.

7.2. Multiple forest effects

The net forest outcome in any given place and time will be influenced by the relative weight of the different effects sketched above. From the literature (Angelsen and Kaimowitz, 1999; Lambin et al., 2001; Busch and Ferretti-Gallon, 2017; Section 6), we have a clear sense of how each variable affects the direction of change through markets, policies, or mixtures of the two, summarized in the order of our conceptual model:

1. Lower global economic growth puts downward pressure on hydrocarbon prices and agricultural and non-agricultural commodities (such as copper, iron, or aluminum);
2. Lower foreign exchange earnings increase devaluations;
3. Lower commodity prices (including currency revaluations) lead to less deforestation;
4. Lower oil prices put downward pressure on biofuel crop prices – among other important knock-on effects on e.g. transport, government finances, etc.;

5. Lower GDP leads to less construction, putting downward pressure on timber prices;
6. Lower GDP leads to less government spending – both for things that lower deforestation (e.g. environmental policing, national parks)...
7. ...and for (the often dominating) things that increase deforestation (e.g. road infrastructure, rural credit, transport subsidies, settlement projects in frontier areas);
8. Lower agricultural household incomes lead to fewer resources to invest in deforesting activities;
9. Lower urban household incomes or loss of non-agricultural rural employment generates urban-to-rural return migration and higher deforestation;
10. Lower household income puts downward pressure on prices of products with high-income elasticities (e.g. proteins, vegetables, ornamentals).

7.3. Net forest outcomes

Through an extraordinary policy response, a sharp but brief deflationary COVID-induced bust in February/March 2020 has given way to an asset- and commodity-inflating phase. If that phase was to continue, with commodity price trends as seen over the last twelve months, this would further increase pressures on tropical forests. For instance, further rising palm-oil prices might endanger recent impressive forest-protective gains in Indonesia and Malaysia.

On the contrary, if a full-fledged economic depression scenario was to still play out, curbing also Chinese commodity demand, then we would see deflationary global outcomes (lower commodity and asset prices, lower production), which on aggregate would likely reduce deforestation, just as has been the case during 2012–15 (Fig. 9). That is, not only would the planet's climate unambiguously receive a passive break from relentlessly increasing CO₂ emissions (Le Quéré et al., 2020), so also would its forests benefit from an “anthropause”, i.e. a break from continuous net conversion to anthropogenic uses (Stokstad, 2020).

Whatever global macroeconomic outcome occurs over the next years, it is likely to come with lots of geographical, and probably temporal variation. In our case studies above, Africa, with its mostly subsistence-led deforestation, was admittedly not well represented. Ultimately, deforestation is about the decisions land stewards are making. Let's assume for a moment I am a poor farmer in a rural forested part of Southern Cameroon. Due to COVID-19 global and national economic impacts, I might lose an off-farm side employment in a timber company, plus remittances from urban relatives, some of whom may return to live with me in the countryside, having lost their urban employment. I could no longer afford to buy rice and would be forced to go back to more slash-and-burn cropping of tubers for my subsistence – the dominating deforestation driver in Cameroon. Hence, I would end up deforesting more than before, like other people who become marginalized from the formal economy.

Conversely, let's assume I am a mid-sized Brazilian farmer, engaging in both cattle ranching with extensive pastures, and some crops for mixed markets. From the COVID-19 economic crisis, I might see poor environmental enforcement as an opportunity to grab land to expand, and a heavy currency devaluation would compensate what I'd lose in terms of falling world-market livestock prices for export (in US\$). However, 80% of my production would be for a national market, where growing “crisis mode” would reduce the consumption of meat and dairy products. I might also be worried about price and exchange-rate fluctuations, and the drying up of national credit. Also, the government would be doing a poorer maintenance of roads and ports. My bottom line would likely be to reduce plans to clear more forest.

The GFW annual tree-cover data have shown us a picture where the net tropical forest outcome for 2020 has, so to speak, produced a tie between Cameroon and Brazil – between the potential prototype land-use decisions of the forcedly expanding subsistence farmer and the

cautiously forest-retaining cattle rancher: basically, pre-existing trends continued. Notably, this more conservative bottom line proved radically different from the biased story that was interpreted inadequately into short-run deforestation alert data, and circumstantial evidence that seemed to conveniently support the idea of a large pickup in deforestation.⁷ Seemingly, there is a lesson to be learned: that we need to first stay tuned for the next bulletins from the global laboratory of macro-economic alchemy. Once these new trends are settled, our conceptual framework above can hopefully assist in predicting what next impacts on forests we should expect, and accordingly address.

Credit authorship contribution statement

Sven Wunder: Conceptualization, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing. David Kaimowitz: Investigation, Formal analysis, Writing - review & editing. Stig Jensen: Investigation, Formal analysis, Writing - review & editing. Sarah Feder: Data curation, Writing - review & editing.

Declaration of Competing Interest

The authors declare to have no conflicts of interest.

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⁷ For the picture from low annual tree-cover loss and high initial GLAD data to be compatible, an initial extra-ordinary pickup in deforestation could have been followed by a compensatory reduction in the rest of 2020. We appreciate unpublished 2020 tree cover data for individual countries, kindly made available to us by Mikaela Weisse (GFW).

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