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Are Voluntary Carbon Markets More Stringent in Crediting than the Clean Development Mechanism?

A Comparison of Public-Private and Fully Private Offsetting Mechanisms’ Ability to Deliver Environmental Integrity using Large-Scale Data

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Thesis submitted for assessment with a view to obtaining the degree of Master of Arts in Transnational Governance of the European University Institute

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ABSTRACT

Voluntary carbon markets (VCMs) have amassed much attention as a novel tool in the fight against climate change. They deliver emissions reductions by enabling mitigation projects to acquire carbon credits for their activity, which they can then sell to generate revenue. Other mechanisms have taken this approach before and commonly achieved unsatisfactory results; the most prominent example being the Clean Development Mechanism (CDM). Whether VCMs are superior to the latter, or just a new try at a failed idea, remains unclear, which is where this thesis contributes. Using publicly available registry data from the CDM and two private regulatory regimes, Verra and Gold Standard (GS), I analyse 10.619 registered projects' estimated annual emissions reductions with the help of descriptive statistics and multivariate regression. I find that, on average, VCMs do not credit projects with higher stringency than the CDM in a statistically significant manner. Qualitative and descriptive analysis provided further evidence for this claim.

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Introduction

Since the adoption of the Kyoto Protocol in 1997, the story of climate governance has increasingly become one of flexibility. Back then, the multilateral sphere set a pivotal precedent for climate policy by relying heavily on market-based approaches in its' three core instruments: the Clean Development Mechanism (CDM), Joint Implementation, and International Emissions Trading. This emphasis on cost-efficient mitigation has spread out to other national and supranational bodies ever since, and it forms the core of the later Paris Agreement's Article 6, which will replace the Kyoto tools in due time.

Beyond the international level, actors and institutions distinct from the nation-state, individually or in cooperation, have also started to partake in global climate action. Non-state actors, ranging from for-profit multinational companies all the way to philanthropic foundations, have opened new, less coercive, and more fluid spheres of governance in this matter. Consequently, carbon markets are increasingly becoming a complex system that often blurs the lines between the public and the private, and between compliance and voluntarism.

Voluntary carbon markets (VCMs) are garnering great attention in this discussion. VCMs are fully privately organised regulatory regimes, utilizing the same project-based "offsetting" logic as the CDM. Despite these similarities, they have previously been referred to as "a site of climate governance beyond the state"[1], given their strong emphasis on non-state actors and soft rules in incentivizing abatement. In theory, this allows them to fill an institutional void that the public sector has left behind, furthering mitigation in a cost-efficient, voluntary, supplementary, and transnational manner[2].

However, whether offsetting can truly achieve desirable outcomes has been contested. Industry, and some academic literature, suggest that VCMs play a crucial role on our path to net-zero and point to recent spikes in carbon offset demand as a clear indicator for its' potential to scale rapidly in the years to come, while retaining or even increasing the market's environmental integrity[3]. From a more academic perspective, it can also

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[1] Philipp Pattberg and Johannes Stripple, 'Beyond the Public and Private Divide: Remapping Transnational Climate Governance in the 21st Century', *International Environmental Agreements: Politics, Law and Economics* 8, no. 4 (December 2008): 378, https://doi.org/10.1007/s10784-008-9085-3.

[2] Frank Biermann et al., 'The Fragmentation of Global Governance Architectures: A Framework for Analysis', *Global Environmental Politics* 9, no. 4 (2009): 14.

[3] Christopher Blaufelder et al., 'A Blueprint for Scaling Voluntary Carbon Markets to Meet the Climate Challenge', Sustainability and Risk Practices (McKinsey & Company, January 2021), https://netzeroanalysis.com/wp-content/uploads/2021/11/03_NEWS__McKinsey_Voluntary-Offset-Growth.pdf; Oliver Miltenberger, Christophe Jospe, and

be argued that such multilevel, polycentric arrangements offer substantial governance benefits, e.g., via their strong degrees of policy experimentation[4].

Still, there is an equal if not larger number of voices approaching VCMs with stark scepticism. Ex-post evaluations of varying scale and scope have suggested that carbon crediting projects, in the CDM or on private VCMs, often do not deliver the environmental, economic, and social advantages they promise[5]. Such insights not only put offsetting at large under scrutiny, but also raise questions as to whether VCMs, as governance structures, are in fact superior to the CDM in their ability to deliver high quality offsets, which is a common position of key voices in this matter.

Notably, this claim has recently been made not only by industry, but also by academia, while neither provide meaningful empirical evidence for VCM superiority in environmental integrity, relative to the CDM[6]. Whether this notion holds up in practice remains unclear. This is concerning, given that poor carbon market design could delay more meaningful mitigation actions by creating a false perception of progress, and by eroding the trust between stakeholders that is needed to achieve effective and equitable responses to climate change in the longer run[7].

This is where the thesis at hand aims to contribute. Its' core research question hence is: "Are VCMs more stringent in crediting than the CDM?". To develop an answer, principal agent theory (PAT) will be utilized as key analytical framework in interpretation, while primarily quantitative methods will be applied. The thesis makes use of large-scale, project-level data that is publicly available on carbon offset registries.

James Pittman, 'The Good Is Never Perfect: Why the Current Flaws of Voluntary Carbon Markets Are Services, Not Barriers to Successful Climate Change Action', *Frontiers in Climate* 3 (14 October 2021): 686516, https://doi.org/10.3389/fclim.2021.686516; Charlotte Streck, 'How Voluntary Carbon Markets Can Drive Climate Ambition', *Journal of Energy & Natural Resources Law* 39, no. 3 (3 July 2021): 367–74, https://doi.org/10.1080/02646811.2021.1881275.

[4] Hanna-Mari Ahonen et al., 'Governance of Fragmented Compliance and Voluntary Carbon Markets Under the Paris Agreement', *Politics and Governance* 10, no. 1 (23 February 2022), https://doi.org/10.17645/pag.v10i1.4759; Katja Biedenkopf et al., 'A Global Turn to Greenhouse Gas Emissions Trading? Experiments, Actors, and Diffusion', *Global Environmental Politics* 17, no. 3 (August 2017): 1–11, https://doi.org/10.1162/GLEP_e_00412.

[5] e.g., Patrick Greenfield, 'Revealed: More than 90% of Rainforest Carbon Offsets by Biggest Certifier Are Worthless, Analysis Shows', *The Guardian*, 18 January 2023, https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe; Barbara Haya, 'Measuring Emissions Against an Alternative Future: Fundamental Flaws in the Structure of the Kyoto Protocol's Clean Development Mechanism', *University of California, Berkeley - Energy and Resources Working Group Working Paper*, no. ERG09-001 (December 2009): 37.

[6] Ahonen et al., 'Governance of Fragmented Compliance and Voluntary Carbon Markets Under the Paris Agreement'; as cited in Regina Annette Betz, *Carbon Market Challenge: Preventing Abuse through Effective Governance* (Cambridge, United Kingdom: Cambridge University Press, 2022), 8.

[7] Robert Passey, Iain MacGill, and Hugh Outhred, 'The Governance Challenge for Implementing Effective Market-Based Climate Policies: A Case Study of The New South Wales Greenhouse Gas Reduction Scheme', *Energy Policy* 36, no. 8 (August 2008): 3009–18, https://doi.org/10.1016/j.enpol.2008.04.010.

The next chapter provides a comprehensive literature review on carbon crediting at-large, developing core hypotheses to be investigated in later analysis. Thereafter, applied methods are discussed in more detail and critically reflecting on the same. The ensuing section provides this thesis' original contribution, linking findings back to the analytical framework in the process, before final conclusions are derived.

Literature review

It is commonly agreed that the theoretical foundation for emissions trading schemes has been laid by Ronald Coase (1960). He argued that, by attaching tradable property rights to distinct units of emissions, and enabling costless bargaining between parties, a cost-efficient, socially optimal equilibrium of pollution abatement can be reached that succeeds in adequate public good provision[8]. Prices of these rights are discovered via buying and selling of units and effectively determined by rights' scarcity and the marginal cost of abatement[9].

This fundamental idea forms the basis of today's flexible carbon trading mechanisms, which can be broadly divided into two categories: Cap-and-trade (CAT) as well as baseline-and-credit (BAC) schemes. CAT markets determine a dynamic, maximum overall emission level and allocate or auction "allowances" or "permits" to emit certain quantities of emissions ex-ante, which can then be traded by holders if they remain below their limit[10]. Administration is public, participation is commonly required by law, and they are often used as stand-alone solution to carbon pricing[11].

VCMs and the CDM, however, rely on BAC systems. They trade emissions reductions or removals that project activities achieved compared to a fictional baseline, i.e., what is commodified is the emissions difference between a business-as-usual scenario and the trajectory brought about by the project[12]. BAC schemes hence do not impose an overall cap on emissions, they are – fundamentally – an abatement cost reduction mechanism and do not necessarily lead to net mitigation overall; offsetting schemes are by default net-neutral in terms of overall emissions, a cause of much debate[13].

BAC units are called "credits", which are issued ex-post, after project implementation, monitoring, impact verification, and certification[14]. Compared to CAT schemes, BAC systems also enable wider participation in credit generation, by state and non-state actors, and they are rarely stand-alone solutions, meaning that BAC tools are often

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[8] Ronald H. Coase, 'The Problem of Social Cost', *The Journal of Law & Economics* 3 (1960): 1–44.
[9] Betz, *Carbon Market Challenge*.
[10] e.g., Betz.
[11] e.g., Betz.
[12] e.g., Betz.
[13] e.g., James Bushnell, 'The Economics of Carbon Offsets', *NBER Working Paper No. 16305*, NBER Working Paper Series, August 2010, 1–16, https://doi.org/10.3386/w16305; Peter Erickson, Michael Lazarus, and Randall Spalding-Fecher, 'Net Climate Change Mitigation of the Clean Development Mechanism', *Energy Policy* 72 (September 2014): 146–54, https://doi.org/10.1016/j.enpol.2014.04.038.
[14] e.g., Betz, *Carbon Market Challenge*.

integrated into other, more encompassing policies[15,16]. While such integration raises theoretical efficiency by enlarging the pool of available abatement options, it often led to arbitrage options in the past, as credits and allowances are imperfect substitutes[17].

On their own, BAC systems' project-based nature renders them unable to support more widespread measures toward emission reduction or removal, a large caveat that warrants caution when relying on them[18]. Their general appeal lies in the fact that not all emissions can fall under centralized, mostly CAT-based regulation, which leaves opportunities for cost-efficient and additional mitigation behind that are worth exploring[19]. Offsetting is a complement to more encompassing policies, filling left-over voids and increasing emissions coverage more generally.

Depending on the mechanism, actors involved can be private or public. While, e.g., all supply side roles are privately held on the VCMs, the CDM uses a public-private mix. The two most important roles in credit creation are the ones of the project developer and the core regulator; the latter may partially outsource regulatory activity and act as standard-setter and credit registry too. While project cycles always start with a project developer designing a mitigation activity that they aim to get credited by a regulatory regime they select, steps thereafter may vary[20]. Table 1 provides a generalization.

As mitigation projects are highly complex and unique, highly specialized yet diverse competencies are required to assess them appropriately; no single actor is likely to possess all these skills at once[21]. Followingly, while core regulators are the main counterpart to developers, devise standards, and run registries, they delegate parts of their gatekeeping and regulation responsibilities to third parties who validate project designs before implementation and verify impacts after implementation (i.e., validation and verification bodies, VVBs), in line with the core regulators' standards[22].

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[15] For example, BAC tools have often been integrated into larger-scale CAT schemes. CDM offset usage for compliance with the Kyoto Protocol is a practical application of this idea on a global layer, as is California's Compliance Offset Program on a sub-national level.

[16] e.g., Betz, *Carbon Market Challenge*.

[17] Noah C. Dormady and Gabriel Englander, 'Carbon Allowances and the Demand for Offsets: A Comprehensive Assessment of Imperfect Substitutes', *Journal of Public Policy* 36, no. 1 (March 2016): 139–67, https://doi.org/10.1017/S0143814X14000336; Robert N. Stavins, 'The Relative Merits of Carbon Pricing Instruments: Taxes versus Trading', *Review of Environmental Economics and Policy* 16, no. 1 (1 January 2022): 62–82, https://doi.org/10.1086/717773.

[18] Haya, 'Measuring Emissions Against an Alternative Future: Fundamental Flaws in the Structure of the Kyoto Protocol's Clean Development Mechanism'.

[19] Bushnell, 'The Economics of Carbon Offsets'.

[20] Vittoria Battocletti, Luca Enriques, and Alessandro Romano, 'The Voluntary Carbon Market: Market Failures and Policy', *European Corporate Governance Institute*, Law Working Paper, no. 668/2023 (March 2023), https://www.ecgi.global/sites/default/files/working_papers/documents/thevoluntarycarbonmarketmarketfailuresandpolicyimplications.pdf.

[21] Battocletti, Enriques, and Romano.

[22] Battocletti, Enriques, and Romano.

Initial credit issuance to the project developer's registry account, i.e., the final step in any regulatory regime's[23] crediting process, is also sometimes referred to as the primary market of a BAC system. Developers can sell these credits to a pre-determined entity or on the spot market, via a broker who facilitates an over the counter (OTC) transaction; in both cases the buyer usually doubles as final demand[24,25]. Equally, developers can sell credits to intermediaries, e.g., an exchange, who can standardize and financialize the credit further[26]. The latter is mostly a VCM phenomenon[27].

Table 1 – Stylized project cycle

Step	Description	Outcome
1.	**Project design** by the project developer; this must include baseline and monitoring methodologies, a monitoring plan for the implementation phase, and all other material project details (e.g., installed capacity); this can include feasibility studies, stakeholder consultations, or similar	Project design document (PDD) sent to VVB for validation assessment
2.	**Project validation** by a third-party validation and verification body (VVB) that is accredited with the core regulator and usually is a private corporation; determines whether PDD meets eligibility criteria, applies methodologies correctly, and provides further quality assurance	Validation report and registration request sent to core regulator
3.	**Project review and registration** by the core regulator and the respective registry; core regulator reviews the validation report provided to it by the VVB/project developer and adds an additional level of scrutiny, requesting revision if appropriate; if satisfied, the core regulator registers the project	Registry entry or status update to "Registered"; project officially validated
4.	**Project implementation** and self-monitoring by the developer; this is the theoretical step of project implementation, though this might have already been achieved before validation; the developer exercises the monitoring plan set out in the PDD, measures and quantifies reductions	Monitoring report and sent to VVB for verification assessment
5.	**Project verification** by a third-party VVB that is accredited with the core regulator, usually is a private entity, and often differs from the validating VVB; reviews monitoring report and provides ex-post assessment of whether reductions requested for crediting were achieved	Verification report and issuance request sent to core regulator
6.	**Project certification and credit issuance** by the core regulator and the respective registry; core regulator reviews verification report provided to it by the VVB/project developer and offers additional scrutiny, requesting revision where appropriate, if satisfied, credits are issued to developer	Registry account of developer credited with emissions reductions; project officially verified

[23] For simplicity, the thesis speaks of the core regulator only when referring to the central mechanism, standard-setter, and registry. VVBs are always clearly delineated from this, while both the core regulator and the VVB are included in the term "gatekeepers" and the term "regulatory regime".
[24] A final consumer of a carbon credit is any entity that buys the credit and retires it on the registry, usually to make an offset claim. In doing so, they pull the credit out of the tradable units universe.
[25] Betz, *Carbon Market Challenge*; Justine Favasuli and Sebastian Vandana, 'Voluntary Carbon Markets: How They Work, How They're Priced and Who's Involved', *S&P Global - Commodity Insights* (blog), 10 June 2021, https://www.spglobal.com/commodityinsights/en/market-insights/blogs/energy-transition/061021-voluntary-carbon-markets-pricing-participants-trading-corsia-credits.
[26] Betz, *Carbon Market Challenge*; Favasuli and Vandana, 'Voluntary Carbon Markets: How They Work, How They're Priced and Who's Involved'; ISDA, 'Role of Derivatives in Carbon Markets' (International Swaps and Derivatives Association, September 2021), https://www.isda.org/a/soigE/Role-of-Derivatives-in-Carbon-Markets.pdf.
[27] ISDA, 'Role of Derivatives in Carbon Markets'.

Technically speaking, one credit represents one metric tonne of carbon dioxide equivalent (mtCO2e) less in the atmosphere, as certified by the regulatory regime[28]. This can be achieved either by avoiding emission in the first place, or by removing already emitted tonnes from the air, biologically or technologically[29]. And carbon credits have some further unique attributes worth mentioning. They are legally treated as commodities, though emissions reductions are intangible assets by nature, which makes them a highly unusual commodity that is hard to measure, quantify, and trace[30].

If private reasons encourage credit purchasing and reduce the theoretical free-rider problem associated with climate action, credits become impure public goods in a societal sense, individualising a global problem[31]. For most parts of the demand side, which buys credits on the spot market rather than in exclusive OTC transactions, credits can also be classified as credence goods[32]. In other words, the true quality of credits is not discernible to the final consumer, even after consumption[33]. For bilateral OTC deals, this tension is likely less pronounced[34].

Generally, even when reductions are bought to enable compliance with other regulations, participants usually need to opt-into such credit usage[35]. Purchases can of course also be completely voluntarily, e.g., by companies to achieve their corporate social responsibility (CSR) goals, or by individuals for social or self-perception reasons, but this has an important implication[36]: The core distinction between VCMs and the CDM is thus not the element of voluntarism, as developers and demand voluntarily produce or use offsets in either case, but the institutional structure of the core regulator.

Carbon credit quality, then, is usually determined by the level of environmental integrity the credit represents. And environmental integrity, in turn, is determined by fulfilment

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[28] Robert C. Brears, *Financing Nature-Based Solutions: Exploring Public, Private, and Blended Finance Models and Case Studies*, Palgrave Studies in Impact Finance (Cham: Springer International Publishing, 2022), https://doi.org/10.1007/978-3-030-93325-8.
[29] Brears.
[30] Battocletti, Enriques, and Romano, 'The Voluntary Carbon Market: Market Failures and Policy'; Betz, *Carbon Market Challenge*.
[31] Atticus Maloney, 'The Voluntary Carbon Market: Managing the Private Provision of Public Goods', *Gettysburg College Headquarters* 1, no. 7 (2022): 1–21; Clive L. Spash and Hendrik Theine, 'Voluntary Individual Carbon Trading', *SRE-Discussion Papers No. 2016/4*, 2016, https://research.wu.ac.at/ws/files/17998544/sre-disc-2016_04.pdf.
[32] Credence goods are sometimes referred to as post-experience goods.
[33] Battocletti, Enriques, and Romano, 'The Voluntary Carbon Market: Market Failures and Policy'.
[34] Aki Kachi and Michel Frerk, 'Carbon Market Oversight Primer' (Berlin, DE: International Carbon Action Partnership, 2013), https://icapcarbonaction.com/system/files/document/carbon_market_oversight_primer_web.pdf.
[35] In other words, with most mixed schemes that use a CAT system with an attached BAC scheme (e.g., the Kyoto Protocol's Assigned Allowance Unit system and the CDM), there is no legal obligation to offset instead of decreasing emissions to stay within the cap. In fact, the principle of supplementarity (i.e., reduce as much as possible before starting to offset) is usually emphasized, so the overall setup features a form of voluntarism comparable to the VCMs.
[36] Brears, *Financing Nature-Based Solutions*; Maloney, 'The Voluntary Carbon Market: Managing the Private Provision of Public Goods'; Andreas Ziegler and Claudia Schwirplies, 'The Determinants of Voluntary Carbon Offsetting: A Micro-Econometric Analysis of Individuals from Germany and the United States', *Verein Für Socialpolitik / German Economic Association*, VfS Annual Conference 2014 (Hamburg): Evidence-based Economic Policy, 100422 (2014), https://ideas.repec.org/p/zbw/vfsc14/100422.html.

of key project criteria, such as additionality, accuracy, leakage, double-counting, permanence, as well as net-positive social and environmental impacts[37]. A project is, e.g., additional if – in the baseline scenario without any crediting – it would not have happened[38]. In practice, additionality has often been operationalized via different sub-concepts such as regulatory additionality (i.e., project not required by law), financial additionality (i.e., project not feasible without offsetting revenue), or barrier testing[39].

Accuracy relates to emissions accounting within the project and ensuring no over- or under-crediting, while leakage refers to the idea that no increase in emissions, or reduction of removals, happens outside of the project, due to the project[40]. Permanence describes the criterium that mitigated carbon will not be fully or partially emitted due to future events, meaning that any activity that used such non-permanent credits is now fully uncompensated for[41]. Finally, no double counting states that the same reduction should not be counted more than once in achieving targets[42].

Relatedly, different project types are already ex-ante to shine or fail in fulfilment of some of these criteria. To provide an example, biological sequestration in ecosystems, facilitated by Nature-based Solutions (NbS) projects, is especially prone to reversal risks, including those that are themselves driven by climate change, such as wildfires[43]. Others might encounter dynamic change in criteria fulfilment; technological projects like wind energy, e.g., might be financially additional in a given year for a given country, but as adoption progresses and costs drop, additionally might not hold the year after.

With the above in mind, one can critically reflect on the incentives and disincentives a BAC system provides. First, there is substantial friction in information discovery for the gatekeepers, i.e., the core regulator and the VVB. True baseline scenarios are private information of developers and – since they can sometimes influence this baseline – a moral hazard issue can ensue[44]. Information asymmetry hinders efficient interaction of

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[37] Brears, *Financing Nature-Based Solutions*; Compensate, 'Reforming the Voluntary Carbon Market' (Helsinki, FIN: Compensate Operations Ltd., 2021), https://downloads.ctfassets.net/f6kng81cu8b8/5vgGIHhsrTAbMnqaDYNGYJ/25a7d0e148a6d15cd10e2409107d7f3d/Reforming_the_voluntary_carbon_market_-_Compensate.pdf.
[38] Brears, *Financing Nature-Based Solutions*.
[39] Brears.
[40] Brears.
[41] e.g., Claudia Herbert et al., 'Carbon Offsets Burning', *Carbon Plan* (blog), 17 September 2020, https://carbonplan.org/research/offset-project-fire.
[42] Brears, *Financing Nature-Based Solutions*; Lambert Schneider et al., 'Double Counting and the Paris Agreement Rulebook', *Science* 366, no. 6462 (11 October 2019): 180–83, https://doi.org/10.1126/science.aay8750.
[43] Brears, *Financing Nature-Based Solutions*; Herbert et al., 'Carbon Offsets Burning'; Nathalie Seddon et al., 'Understanding the Value and Limits of Nature-Based Solutions to Climate Change and Other Global Challenges', *Philosophical Transactions of the Royal Society B: Biological Sciences* 375, no. 1794 (16 March 2020): 20190120, https://doi.org/10.1098/rstb.2019.0120.
[44] Bushnell, 'The Economics of Carbon Offsets'; Knut Einar Rosendahl and Jon Strand, 'Simple Model Frameworks For Explaining Inefficiency Of The Clean Development Mechanism: Simple Model Frameworks For Explaining Inefficiency Of The Clean Development Mechanism', *World Bank Policy Research Working Papers*, 22 May 2009, https://doi.org/10.1596/1813-9450-4931.

developers with gatekeepers and, in extension, with final demand; asymmetry can only be tackled with strict monitoring, reporting and verification (MRV), which usually is prohibitively costly or complicated in principal-agent setups[45].

Second, supplying offsets is particularly attractive for projects whose true baseline is lower than the regulators' estimates, allowing them to get paid for reductions that would have happened anyway[46]. Followings, developers self-selecting into regulatory regimes creates adverse selection strains: Less or non-additional projects could sort themselves into the most lenient mechanisms, thereby increasing overall supply, depressing prices, crowding out projects of higher environmental integrity that were reliant on higher prices, and – in the worst case – leading to market unravelling[47].

However, if regulators' estimated baseline is unduly stringent and filters too strongly, e.g., because they do not have perfect information on the aggregate distribution of baselines which is arguably not a strong assumption, the second problem potentially becomes less severe[48]. Relatedly, one should also not disregard the option that over-credited offsets could get balanced out partially or fully by under-credited emissions reductions elsewhere in the market, without excessively sacrificing supply, due to the dual effect of imprecise baselines[49]. Over- and under-shooting might balance naturally.

Third, there can be incentive alignment between actors to inflate credit numbers. Project developers' desire to maximize crediting amounts is mostly economically motivated[50]. Demand, on the other hand, likely is unable and unwilling to punish low-quality offsets, given the credit is a credence good, for the quality of which they cannot be held accountable, and higher supply decreases prices, enabling them to achieve climate goals more cheaply[51]. Ideally, inflationary tendencies should thus stop with the regulatory regime, which encounters reputational risk if it negligently over-credits[52].

However, in VCMs the issuer-pays principle applies. In other words, most revenue of gatekeepers comes from the same project developers they should be assessing

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[45] Bushnell, 'The Economics of Carbon Offsets'; Bengt Holmström, 'Moral Hazard and Observability', *The Bell Journal of Economics* 10, no. 1 (1979): 74, https://doi.org/10.2307/3003320.
[46] Bushnell, 'The Economics of Carbon Offsets'.
[47] George A. Akerlof, 'The Market for "Lemons": Quality Uncertainty and the Market Mechanism', *The Quarterly Journal of Economics* 84, no. 3 (August 1970): 488, https://doi.org/10.2307/1879431; Carolyn Fischer, 'Project-Based Mechanisms for Emissions Reductions: Balancing Trade-Offs with Baselines', *Energy Policy* 33, no. 14 (September 2005): 1807–23, https://doi.org/10.1016/j.enpol.2004.02.016.
[48] Bushnell, 'The Economics of Carbon Offsets'.
[49] Antonio Bento, Ravi Kanbur, and Benjamin Leard, 'On the Importance of Baseline Setting in Carbon Offsets Markets', *Climatic Change* 137, no. 3–4 (August 2016): 625–37, https://doi.org/10.1007/s10584-016-1685-2.
[50] Betz, *Carbon Market Challenge*; Felix Ekardt and Anne-Katrin Exner, 'The Clean Development Mechanism as a Governance Problem', *Carbon & Climate Law Review* 6, no. 4 (2012): 396–407.
[51] Battocletti, Enriques, and Romano, 'The Voluntary Carbon Market: Market Failures and Policy'.
[52] Battocletti, Enriques, and Romano.

critically, an economic incentive that might outweigh the reputational risk concern[53]. Even further, both the core regulator's and the VVB's revenue are often directly proportional to the amount of credits they issue to the project, directly incentivizing credit inflation for all actors[54,55]. This could leave only out-of-transaction actors with the right motives to pursue detection and punishment of credit inflation[56].

Compared to theory, empirical studies on BAC systems' integrity are scarce and centre on the CDM. Drew and Drew (2010) perform a case study on the CDM project cycle and posit that the process of establishing and verifying additionality is a key systemic weakness that must be addressed. Calel et al. (2021) analyse 472 wind farm projects in India that were credited by the CDM; they find that 265 of them, or 52 percent, were blatantly infra-marginal, i.e., there were similar projects in the same state that were strictly less profitable and happened without crediting – additionality was unlikely.

Wozny et al. (2022), e.g., analyse internal rate-of-return (IRR) CDM data and find that the likelihood of project additionality largely depends on the project type, though more additional projects do not necessarily achieve higher final credit prices. Put differently, offset prices cannot be used as a signal for climate integrity from an additionality standpoint[57]. Zhang and Wang (2011) look at co-benefits and additionality by analysing CDM projects' capacity to reduce sulfur-dioxide emissions in China; they find that projects had no statistically significant effect on them, while additionality was doubtful.

Relatedly, Cames et al. (2016) critically review CDM rules and their application, finding that 85 percent of projects and 73 percent of all credits supplied there between 2013 and 2020 have a low likelihood of being additional and non-overestimated[58]. Erickson et al. (2014) explore the additionality and crediting with a view to develop scenarios of net emissions impact of the CDM and find that net mitigation of the full system hinges on additionality of selected, core project types; they also provide empirical evidence for the dual effect of imprecise baselines, as outlined by Bento et al. (2016).

Alongside additionality, some of the incentive problems discussed above were also explored empirically for the CDM. Chen et al. (2021), e.g., consider data on over 2000

[53] Battocletti, Enriques, and Romano.
[54] One example of a VCM in which both the regulator's and the VVB's commission size depend on the amount of credits issued to the project is Verra.
[55] Battocletti, Enriques, and Romano, 'The Voluntary Carbon Market: Market Failures and Policy'.
[56] Battocletti, Enriques, and Romano.
[57] Florian Wozny et al., 'CORSIA—A Feasible Second Best Solution?', *Applied Sciences* 12, no. 14 (13 July 2022): 7054, https://doi.org/10.3390/app12147054.
[58] Martin Cames et al., 'How Additional Is the Clean Development Mechanism?' (Berlin, DE: Öko-Institut e.V., March 2016), https://climate.ec.europa.eu/system/files/2017-04/clean_dev_mechanism_en.pdf.

CDM projects to analyse biased reporting by the project developers in their IRR projections at the time of application. They find that expected IRRs of projects, an important determinant of CDM admission for financial additionality reasons, are downwardly biased and negatively associated with expected size of returns, i.e., estimated reduction amount, though monitoring can mitigates some of this distortion[59].

This provides empirical evidence for the asymmetric information-induced moral hazard highlighted by Rosendahl and Strand (2009). Further, Flues et al. (2010) analyse data for 250 methodologies and about one thousand projects discussed by the CDM, finding that, aside from formalized criteria, political-economic variables co-determine the final decision. This points toward potential regulatory bias, even in absence of issuer-pays problems. Buen and Michaelowa (2009) list evidence for corruption at the project approval by the host country stage of the CDM cycle, again putting integrity into doubt; Nguyen et al. (2011) and Wood et al. (2016) substantiate this claim for other countries.

More recently, another strand of literature looked at California's carbon offset program, which feeds into the states' CAT system. Badgley et al. (2022) use comprehensive offset project records, alongside forest inventory data, to evaluate this mechanism design and find that large credit volumes are awarded to projects with carbon stocks that far exceed regional averages. Coffield et al. (2022) use remote sensing-based datasets to evaluate carbon trends and harvest histories of thirty-seven such carbon sink projects, finding that their sequestration was not additional.

Haya et al. (2023) analyse offset methodologies for improved forestry management in this program, finding that baseline determination is the key governance process enabling or barring credit inflation; however, standardized baselines offer only the ability to reduce, not eliminate, these inflationary risks[60]. Anderson et al. (2017) provides a further, descriptive analysis, concluding that the Californian program does not inhibit overall mitigation and that it is additional, contradicting Coffield et al. (2022). Herbert et al. (2020) show that future wildfire-related reversal risks are not sufficiently covered by the program's buffer pool.

Empirical work on fully private VCMs is limited and has a strong focus on nature-based climate solutions, leaving plenty of governance questions unanswered. Nevertheless,

[59] Hui Chen, Peter Letmathe, and Naomi Soderstrom, 'Reporting Bias and Monitoring in Clean Development Mechanism Projects', *Contemporary Accounting Research* 38, no. 1 (March 2021): 7–31, https://doi.org/10.1111/1911-3846.12609.
[60] Barbara Haya et al., 'Managing Uncertainty in Carbon Offsets: Insights from California's Standardized Approach', *Climate Policy* 20, no. 9 (20 October 2020): 1112–26, https://doi.org/10.1080/14693062.2020.1781035.

Guizar-Coutiño et al. (2022) quantify the performance of a sample of forty avoided deforestation projects in nine countries, certified by one such private regulatory regime, and find that deforestation was, on average, reduced by only 47% compared to baseline, that effects were larger on sites located in high-deforestation settings, and that leakage was unsubstantial.

West et al. (2020) examine the causal effects of twelve voluntary projects focusing on avoided deforestation in the Brazilian Amazon and find that the methodologies applied overstate impacts on avoided deforestation and climate change mitigation. West et al. (2023) examine twenty-seven conservation projects in six countries and find that most projects did not reduce deforestation and that those which did reduce it often overstated their impact. All three of these studies used satellite imagery and synthetic control methods for causal inference.

Notably, none of the empirical literature reviewed differentiates clearly between the CDM and VCMs when considering outcomes, or looks at them comparatively at all. Wozny et al (2022) also directly infer from one to the other without any qualification of this equivalency assumption. However, from a more general governance perspective, they are clearly distinct: One was the result of multilateral ambition and has explicit developmental ambition, the others are fully private regulatory regimes, emphasizing voluntarism and attracting very different sources of demand.

No scientific endeavour has tried to empirically explore whether the CDM or VCMs are relatively more stringent in crediting. This thesis aims to help fill this gap. As such, it builds on Ahonen et al (2022), Bushnell (2010), Chen et al. (2021), and Wozny et al. (2022). Additional relevance is given to this endeavour by the fact that some nation-states and international institutions already allow VCM credits for compliance usage[61], and that Article 6 negotiations have not closed the door to the VCMs either[62]. Empirical insights on VCMs are scarce, added value of a this thesis can be considered large.

[61] e.g., the International Civil Aviation Organization's Carbon Offsetting and Reduction Scheme for International Aviation.
[62] Bassam Fattouh and Andrea Maino, 'Article 6 and Voluntary Carbon Markets', *The Oxford Institute for Energy Studies - Energy Insight* 114 (May 2022): 19.

Methods

The thesis utilizes predominantly quantitative methods to compare the CDM and private VCMs in three-steps. First, it contrasts selected mechanisms qualitatively, highlighting structural and procedural differences. Subsequently, a quantitative analysis is conducted, paying particular attention to the core project-level outcome considered here: Estimated annual emissions reductions. This will be done via simple descriptive statistics, as well as – in a third step – more advanced econometric means. A final section discusses results and builds a foundation for the conclusion thereafter.

To enable production of meaningful insights, principal-agent theory (PAT) is drawn upon as analytical framework throughout this analysis. PAT was first developed in the 1970s and is broadly situated at the intersection of Economics and Organizational Studies. It views organizations as nexus of contracts between individuals and focusses on issues that arise when a principal (here, the regulator) contracts out decision-making authority, or tasks more generally, to an agent (here, the project developer), acting on their behalf in this setup[63]. Such situations are common in everyday life and yield conditions that can have adverse consequences for overall welfare maximization.

Theory predicts that, in cases where both principal and agent are utility maximizers, the latter may pursue actions that do not maximize the welfare of the principal, given their self-interest[64]. Principal-agent setups are thus assumed to create "agency costs". These consist of costs associated with trying to align agents' incentives[65], and a residual loss of the principal due the remaining divergence between them and the agent, even after all additional alignment measures are accounted for[66]. At its' heart, the problem PAT tries to understand is thus one of dealing with asymmetric information between two actors that stand in a contractual relation, which can take many forms.

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[63] e.g., Eugene F. Fama and Michael C. Jensen, 'Separation of Ownership and Control', *The Journal of Law and Economics* 26, no. 2 (June 1983): 301–25, https://doi.org/10.1086/467037; Sanford J. Grossman and Oliver D. Hart, 'An Analysis of the Principal-Agent Problem', *Econometrica*, Huebner International Series on Risk, Insurance and Economic Security, 51, no. 1 (1992): 302–40, https://doi.org/10.1007/978-94-015-7957-5_16; Holmström, 'Moral Hazard and Observability'; Michael C. Jensen and William H. Meckling, 'Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure', *Journal of Financial Economics* 3, no. 4 (October 1976): 305–60, https://doi.org/10.1016/0304-405X(76)90026-X; Stephen A. Ross, 'The Economic Theory of Agency: The Principal's Problem', *The American Economic Review* 63, no. 2 (1973): 134–39.

[64] e.g., Jensen and Meckling, 'Theory of the Firm'.

[65] These include monitoring costs of the principal, who may wish to monitor the agent in task fulfilment, and bonding costs of the agent, a cost they might encounter as result of trying to prove to the principal that they are in fact acting in their interest (e.g., using state-of-the-art carbon measurement techniques during implementation).

[66] e.g., Jensen and Meckling, 'Theory of the Firm'.

In the offsetting case, e.g., agents could create residual loss in form of reputational damage for the principal, and capture pecuniary benefits for themselves, by inflating their baselines. This will raise estimated annual emissions reductions of the project and – in extension – their revenue, while leading to credit oversupply on the market[67]. PAT theory hence has great explanatory power for BAC systems, which likely is why Bushnell (2010), Bushnell (2011), as well as Heal (2022) follow this tradition in research too. This thesis continues their thoughts and builds bridges to empirics.

Identification strategy

The comparative nature of this thesis necessitates case selection as a first step. The literature review suggested that the CDM is not only the most important public-private offsetting mechanism in a general sense, but that it is also the one for which most academic knowledge is available. It followed naturally to use the CDM as public-private mechanism in this comparison. For VCM cases, the method of difference was applied in selection: Mechanisms were selected based on them being as similar to the CDM as possible, ideally only differing from it in the fact that they are fully private regimes so as to enable robust identification of probable causes for outcome divergence.

Desktop research revealed that there are two private players that dominate the VCM arena at-large[68]: Verra and Gold Standard (GS). Like the CDM, they also operate on a global scale, produce credits that are frequently allowed into compliance usage, and have even utilized some of the CDM's third-party VVBs, took over CDM projects, or applied CDM methodologies. By including these two in analysis, the thesis is able to generate knowledge that is relevant for around 88% of all credits issued across VCMs to date[69]. It followed logically to make this a three-case comparison.

After case selection, the key outcome variable had to be established. Previous work almost exclusively looked at economic outcomes of the CDM for data availability reasons and because any non-economic outcome risks not capturing the central incentives that guide individual behaviour in a market setting. However, it is also true

[67] e.g., Jensen and Meckling.
[68] e.g., Climate Focus, 'Registrations and Credit Issuances', The Voluntary Carbon Market Dashboard, 2023, https://app.powerbi.com/view?r=eyJrIjoiNGI5ZDY1ZWUtZGU0NS00MWRmLWFkNjQtMTUyYTMxMTVjYWQyIiwidCI6IjUzYTRjNzZkLWI2MjUtNGFhNi1hMTAzLWQ0M2MyYzIxYTMxMiIsImMiOjl9&pageName=ReportSection68c2510fa4171bdf82a9; World Bank, 'State and Trends of Carbon Pricing 2022', State and Trends of Carbon Pricing (Washington, DC: World Bank, 24 May 2022), https://openknowledge.worldbank.org/entities/publication/a1abead2-de91-5992-bb7a-73d8aaaf767f.
[69] Climate Focus, 'Registrations and Credit Issuances'.

that economic outcomes can only indirectly proxy for non-economic results. Other indicators might provide better foundations to analyse environmental integrity. One such indicator, attainable for all three cases, can be found in projects' "estimated annual emissions reductions in mtCO2e".

Using this as outcome simplifies generating stringency-related insights: There is a direct link between estimated reduction over-estimation and credit inflation. Estimated annual reductions are, effectively, a climate potency score for projects that is granted by the regulator; as such, they reflect virtually all core issues of interest here in a single, discrete, numeric variable. In addition, estimates are an interim outcome in the project cycle, determined first by the project developer in the project design document (PDD), before registration. Whether they carry economic weight depends on the prices individual credits fetch after verification[70]. Principal-agent tensions might thus be more pronounced for this interim outcome than for final ones. Given its' availability and explanatory strength, analysis thus uses estimated reduction values as key outcome.

Descriptive, quantitative analysis explores the projects registered in the three mechanisms along key environmental integrity criteria. Project developers are practically free to choose their regulatory regime and given projects might move between the cases too, some dis-entangling of data is required. To enable clear-cut insights, the full sample of registered projects is broken down into two parts: Projects that have transitioned from the CDM to one of the two VCMs, and projects that have not. These two are analysed separately, enabling distinct insights into primary project sorting, i.e., pre-registration, intra-registry composition, average crediting amounts across sub-samples, and secondary project sorting, i.e., from the CDM to the VCMs.

Finally, the analysis will move to multivariate ordinary least squares (OLS) regression, using intra- and inter-registry datasets. OLS regression is a statistical tool used to model relations between a dependent and one or more independent variables. To put it simply, OLS estimation minimizes the sum of squared differences between observed results and predicted outcomes of the model fitted to them, finding the most appropriate coefficients for each explanatory variable in the process. OLS regression is a popular tool for understanding relations in large-scale data and allows for easy

[70] In other words, if prices are assumed to be exogenous (fixed), the revenue of project developers is directly proportional to the estimated emissions reductions granted to them. However, if prices are endogenous (variable), it might hold that there is a causal link between amounts of emissions reductions granted to a project and the price of the individual credit: If lower quantity projects are perceived by the demand side to be of higher quality, their credits might achieve higher prices, potentially increasing revenue overall, despite decreasing quantity.

operationalization of the core question of this thesis, i.e., whether VCMs are in fact more stringent than the CDM in crediting: Controlling for project fundamentals, projects that were registered with Verra or GS should, on average, be granted significantly lower reduction amounts than a CDM project if VCMs are indeed more stringent.

This idea directly builds on prior research showing that CDM projects are often non-additional and have frequently been awarded inflated credits[71]. Hence, if VCMs are a better alternative, then they should underestimate emissions reductions relative to the CDM. This approach is consequently not one that will yield absolute statements: Whether Verra and GS are stringent enough or not is a different matter. Rather, what can be answered with this setup is whether VCMs are statistically associated with lower crediting, i.e., *relatively more stringent* than the CDM, which serves as baseline, arguably insufficient scenario. Formally, the full model looks as follows:

$$EMI\_RED_i = \beta_0 + \beta_1 ACT\_TYPE_i + \beta_2 ACT\_SIZE_i + \beta_3 ACT\_REGION_i + \beta_4 REG\_YEAR_i + \beta_5 ISS\_DUMMY_i + \beta_6 VCM\_DUMMY_i + \epsilon$$

where EMI_RED_i … estimated annual emissions reductions of project i in metric tonnes of CO2-equivalent, a discrete, numeric variable, ACT_TYPE_i … activity type of project i following UN Environmental Programme DTU classification, a categorical variable, ACT_SIZE_i … activity size of project i as suggested by Clean Development Mechanism terminology, a dummy variable, ACT_REGION_i … region of the of project i's host country as classified by the latest World Bank system, a categorical variable, REG_YEAR_i … of project i's registration year as fixed effects, a categorical variable, ISS_DUMMY_i … a dummy equalling one if project i had an accessible first credit issuance date at the time of retrieval, and VCM_DUMMY_i … a dummy equalling one if project i was registered with a private VCM. The remaining elements are β_0 … intercept capturing effects for observations where all explanatories are zero, β_{1-6} … variable coefficients as per the model, and ϵ … error term.

This regression, and partial derivates thereof, will be run for non-transitioned projects only, as featuring transitioned projects would require different specification[72]. The smaller model, excluding the VCM dummy, will be run for pure, i.e., non-transitioned, observations within each registry and across all of them before engaging in the full specification. OLS is a great tool for this purpose, though several assumptions are required: Multicollinearity[73] must be absent, homoscedasticity[74] must hold, and explanatories need to be independent for coefficients to be causally interpretable.

[71] e.g., Haya, 'Measuring Emissions Against an Alternative Future: Fundamental Flaws in the Structure of the Kyoto Protocol's Clean Development Mechanism'.
[72] See section "Assets and limitations" in the Methods chapter.
[73] Multicollinearity describes the circumstance where several of the independent variables in a model are correlated. Two variables are considered perfectly collinear if their correlation coefficient is one or minus one, i.e., they move in direct proportion.
[74] Homoscedasticity refers to the assumption that all explanatory variables have similarly distributed variance.

Navigating these assumptions can only be done to a certain extent for the full sample. Perfect collinearity, e.g., between regulator-specific methodologies and the VCM dummy, must be remedied. The sample also needs to be narrowed to observations registered post-2009, the first year all cases were active simultaneously. But even with best-possible precautions, this analysis cannot yield causal interpretation, as projects are not randomly assigned to mechanism. Their sorting ability creates a variable independence issue, and potentially reverse-causality – a form of endogeneity[75]; coefficients must thus be interpreted with caution and can only provide measures of association.

Data preparation

Quantitative data are publicly available project-level data retrieved from the respective mechanisms' registries on April 26th, 2023[76]. These initial downloads featured a total of 19.594 projects. After exclusion of non-registered projects, deletion of incompletes, removal of mechanism-internal duplicates or conversions, and wider data harmonization, 11.787 registered projects remained, which were split approximately 60-20-20 between the CDM and the two private markets[77]. This sample was then divided into two parts, projects that had transitioned from the CDM to a VCM, a total of 1.778 observations[78], and those that had not, the remaining 10.009. While transitioned projects did not need further consolidation, the pure projects sub-sample then had to be narrowed to ventures that were registered during or after 2009, which left 8.845 final observations for this sub-sample.

Data harmonization steps are discussed in more detail in the Annex, which also provides a project type categorization table and short descriptions of all variables used. Additionally, an Online Annex features all files required to recreate the findings discussed here from scratch[79]. Overall, a strong effort was made to include as little

[75] In other words, project developers could sort themselves into a mechanism because they think they will get higher estimated emissions reductions there. In this case, it might well be that it is not the mechanism that is the cause for over-crediting for a project, but the over-crediting of the registry that causes the project to go to that mechanism. In this case the VCM dummy is linked to the error term which creates non-negligible endogeneity.
[76] For the CDM, the registry is accessible here: https://cdm.unfccc.int/Projects/projsearch.html.
For Verra, the registry is accessible here: https://registry.verra.org/app/search/VCS/All%20Projects.
For Gold Standard, the registry is accessible here: https://registry.goldstandard.org/projects?q=&page=1.
[77] See section "Data preparation" in the Annex chapter. If not otherwise specified, R was used to do all data-related tasks.
[78] Overall, 884 pairs, i.e., one-for-one matches, or triplets, i.e., projects that first moved from the CDM to one of the VCMs before moving from one VCM to the other VCM, were identified.
[79] The Online Annex is accessible here: https://drive.google.com/drive/folders/1FHX5mYEa5ckMX3AYQXgG39eCXfG2M-L5?usp=sharing

manual steps as possible throughout preparation, to maximize reproducibility and to keep raw data integrity intact whenever meaningful and feasible. To provide an example, datapoints needed for analysis that were not part of the main downloads were either merged in using other available datasets from the same websites or web-scraped using automation[80]; collection by hand was only done if all else failed. Harmonization changes were kept to a minimum by taking the CDM as base and harmonizing both VCMs into the terminology and categorizations of the former.

Assets and limitations

Given project's unique character, the first-best solution to analysing credit inflation is to assess activities in case-by-case, utilizing advanced, state-of-the-art natural science methods and on the ground inspections, auditing, and measurement. This was not an option for this thesis, making the approach taken here a second-best solution, necessitated by the time and financial constraints. Insights thus are mostly exploratory and provide a high-level assessment, which may nevertheless warrant further investigation in the future. As it was clear the thesis will be of second-best nature, taking a large-scale quantitative approach, which allows reliance on the law of large numbers, was arguably the most sensible solution available. Other options, i.e., small sample case studies using accessible documents, were unlikely to yield inductive capacity and risked using biased information without being able to reflect on the same.

Exploring project-level emissions reductions and taking them as an outcome is a novel approach. There is uncertainty as to what explanatory value this variable actually offers; this, however, also gives the approach taken here more relevance. Another key consideration to take into account is that the larger, pure sub-sample of non-transitioned observations analyses only projects registered in or after 2009. This is after several major reforms had taken place in the CDM[81], which may bias findings against VCMs as one compares them to a less issue ridden CDM. This cannot be avoided tidily in regression, but the descriptive analysis will feature pre-2009 values for the CDM to remove some of this bias. On the final regression specification, estimated coefficients can only serve as estimates of association, not cause. This is a large

[80] All web-scraping was performed with Python.
[81] e.g., Chen, Letmathe, and Soderstrom, 'Reporting Bias and Monitoring in Clean Development Mechanism Projects'.

caveat, but necessitated by the fact that simple descriptive statistics are not rigorous enough to give an acceptable answer to the research question.

In theory, the approach taken here could be improved by including an instrumental variable[82] in the regression model to remedy the reverse causality concern or by using the sub-sample of transitioned projects. The former cannot be done due to data availability and the latter, while avoiding reverse causality, comes with its' own set of concerns[83]. Other than the regression model, however, the approach taken here is close to the optimal second-best solution: It covers large parts of the VCM and, by including the CDM as baseline, the core BAC system of interest for research. Descriptive statistics can provide meaningful insights without great statistical concern, using estimated annual emissions reductions as outcome creates an additional, original contribution, and the setup overall allows finding an answer to a pressing question in climate policy.

[82] In other words, if one can include a variable that heavily influences the sorting decision but has no relation with the independent variable, this endogeneity can be dealt with. An obvious way to do this here would be to include differences in prices between the CDM and VCMs, potentially averaged over the year prior to registration, to capture economic signals faced by the developer at the time of the sorting decision. Then, assuming these price signals heavily influence sorting and are unrelated with estimated emissions reductions, more causal interpretation of the VCM dummy might be possible.

[83] Crucially, true panel data is only available for transitioned projects, i.e., one cannot reliably observe the outcome variable for projects that stuck with their mechanism at multiple points in time. Only observations that switched from the CDM to VCMs between timepoints t and $t + X$, where t is the original CDM registration date and $t + X$ is the later VCM registration date, would be featured, which obviously biases findings. Again, there are remedies that could make inclusion of non-transitioned projects feasible in a non-panel setup, but this exceeds the scope of the analysis here.

Are VCMs More Stringent in Crediting than the CDM?

Case comparison

For BAC systems to function properly, regulators need to filter out non-additional or otherwise flawed projects and award relatively more credits to those that are more climate potent. They are, hence, conceptually akin to credit rating agencies, though the rating comes in form of emissions reductions granted, not a categorical scale[84]. Continuing this analogy, the supply side of any carbon offset markets too can be described as a principal-agent problem, between regulator[85] and project developer. As such, economic and environmental agency costs may arise from dividing up who makes decisions about and implements projects, i.e., the developers, and who carries the reputational consequences of these actions, i.e., the regulatory regime.

These agency costs may vary depending on how the mechanism is governed, putting governance parameters, such as the design of contractual relations between involved parties, into focus. Here, the CDM, Verra, and Gold Standard (GS) are considered from this perspective. The thesis views them, effectively, as climate potency rating agencies, where the clients are the projects, and the scores are the estimated annual emissions reductions. Notably, all three are rather dynamic regimes, their exact specifications vary over time; to develop a useful base for analysis, the initial qualitative comparison consequently centres on research-relevant governance dimensions that are comparatively static throughout the observation period.

The CDM is one of the three flexible tools of the Kyoto Protocol and allows climate change mitigation projects in developing countries to earn certified emissions reductions (CERs), making it a dual, climate policy- and development policy-related instrument[86]. CERs can be bought by industrialized countries to meet Kyoto targets, or by other actors on a voluntary basis[87]. CDM revenue, on the other hand, stems both from UN funding and from registration fees; the latter are proportional to the crediting

[84] e.g., Chen, Letmathe, and Soderstrom, ‘Reporting Bias and Monitoring in Clean Development Mechanism Projects’.
[85] “Regulator” refers to both, the standard setter (including the registry) and the third-party VVB.
[86] UNFCCC, ‘Home’, UNFCCC - Clean Development Mechanism (CDM), 2023, https://cdm.unfccc.int/index.html; UNFCCC, ‘About’, UNFCCC - Climate Neutral Now, 2023, https://cdm.unfccc.int/about/index.html.
[87] UNFCCC, ‘Home’; UNFCCC, ‘About’; UNFCCC.

amount and a two percent levy is placed on issuances which flows into the UNFCCC Adaptation Fund[88,89].

The mechanism is supervised by an Executive Board (EB), hosted by the UNFCCC Secretariat and accountable to the Conference of the Parties to the Kyoto Protocol, a multilateral forum[90]. The EB is supported by five internal bodies with specialized technical knowledge and serves as point-of-contact for project participants in matters of registration and issuance; it has twenty members, selected to be representative of UN regions and serving time-limited terms[91]. Methodologies may be proposed bottom-up by project participants or top-down by the EB; the same holds for revisions and clarifications [92]. Standardized baselines[93] are allowed, but seldomly applied[94]. In validation, the CDM relies on the help of Designated Operational Entities (DOEs; i.e., the VVB), which are usually private, and Designated National Authorities (DNAs)[95].

DOEs need to be accredited and designated by the EB, which also reviews their performance regularly[96]. Similar to the EB members, DOEs cannot have any conflicts of interest with project they engage in, the EB may allow a given DOE to perform both validation and verification for a single project, though this is not the default option[97]. DOEs also cannot have pending judicial processes, must be financially stable, and conduct recurring competence analyses to ensure they hold the necessary human capital to conduct their operations[98]. New DOEs must pass vetting by an accreditation panel that, if applicable, recommends accreditation to the EB, which has the final say[99].

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[88] The UNFCCC Adaptation Fund finances adaptation projects and programmes in developing country parties to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change.
[89] Katharina Michaelowa and Axel Michaelowa, 'The Growing Influence of the UNFCCC Secretariat on the Clean Development Mechanism', *International Environmental Agreements: Politics, Law and Economics* 17, no. 2 (April 2017): 247–69, https://doi.org/10.1007/s10784-016-9319-8; UNFCCC, 'CDM-EB54-A29' (UNFCCC - Clean Development Mechanism (CDM), 28 May 2010), https://cdm.unfccc.int/UserManagement/FileStorage/9GCQ6SNRJKF7TXPDU4IZ5O0BLV1YE8; UNFCCC, 'Home'.
[90] UNFCCC, 'Governance', UNFCCC - Clean Development Mechanism (CDM), 2023, https://cdm.unfccc.int/EB/governance.html.
[91] UNFCCC, 'FCCC/KP/CMP/2005/8/Add.1' (United Nations, 20 March 2006), https://unfccc.int/resource/docs/2005/cmp1/eng/08a01.pdf; UNFCCC, 'EB69, Annex 1' (UNFCCC - Clean Development Mechanism (CDM), 13 September 2012), EB69, Annex 1; UNFCCC, 'Governance'.
[92] UNFCCC, 'CDM-EB70-A36-PROC' (UNFCCC - Clean Development Mechanism (CDM), 1 September 2017), https://cdm.unfccc.int/sunsetcms/storage/contents/stored-file-20170830140938685/Meth_proc09.pdf.
[93] Standardized baselines refer to baseline methodologies that allow demonstration of additionality and reduction calculation in a simplified format by declaring that certain project activities, when part of specified sectors and situated in referenced countries, can practically be assumed additional, if certain conditions are met. In theory, this reduces transaction costs for project developers and increases transparency of the overall system, as it standardizes some of the key approval steps across projects.
[94] UNFCCC, 'CDM-EB70-A36-PROC'; UNFCCC, 'CDM-EB63-A28-PROC' (UNFCCC - Clean Development Mechanism (CDM), 14 December 2020), https://cdm.unfccc.int/sunsetcms/storage/contents/stored-file-20201215164053232/meth_proc07.pdf; UNFCCC, 'Standardized Baselines under the Clean Development Mechanism', UNFCCC - Clean Development Mechanism (CDM), 2023, https://cdm.unfccc.int/about/standardized_baselines/index.html.
[95] UNFCCC, 'Governance'.
[96] UNFCCC, 'FCCC/KP/CMP/2005/8/Add.1'; UNFCCC, 'Designated Operational Entities', UNFCCC - Clean Development Mechanism (CDM), 2023, https://cdm.unfccc.int/DOE/index.html.
[97] UNFCCC, 'FCCC/KP/CMP/2005/8/Add.1'.
[98] UNFCCC, 'CDM-EB46-A02-STAN' (United Nations Framework Convention on Climate Change, 1 March 2018), https://cdm.unfccc.int/sunsetcms/storage/contents/stored-file-20180323155152132/accr_stan01.pdf.
[99] UNFCCC, 'Designated Operational Entities'.

The CDM project development cycle starts with the project developer designing a project idea, and potentially a feasibility study, before creating the Project Design Document (PDD) which it then sends to the DNA of their home country[100]. In the PDD, project participants have to apply a fitting methodology of their choice to their proposed activity, demonstrate the project's additionality, establish a baseline scenario from which the project diverges, estimate annual emission mitigation, and develop a monitoring plan; the PDD must cover any information that is material to the regulator[101].

The DNA then checks the PDD against its' guidelines, as well as sustainable development criteria, before – if appropriate – issuing a letter of approval developers; thereafter, they pass the PDD on to the DOE they selected and contracted[102]. The DOE evaluates the PDD and – if warranted – issues a validation report alongside a registration request to the EB; the latter performs a completeness check, partially supported by the CDM Secretariat, and – if no Kyoto party to the project or less than three board members request revision – registers the activity[103].

Implementation is monitored by the project participants, while ex-post verification is again the domain of DOEs; they certify impacts and request credit issuance at the EB[104]. The EB goes through the same loop as it did for validation, before issuing credits to the developer's account, if warranted[105]. CER demand might meet supply at any stage in this cycle, from the PDD draft onward[106]. In addition to this default procedure, participants may seek certification from other private entities that offer quality labels for CERs, e.g., if they provide substantial co-benefits.

One such actor is GS, a non-profit organization headquartered in Geneva and founded by the World Wildlife Foundation (WWF), alongside other international NGOs, in 2003[107]. GS's heart is its' Secretariat, which is overseen and guided by the Foundation

[100] Anja Kollmus, Helge Zink, and Clifford Polycarp, 'Making Sense of the Voluntary Carbon Market: A Comparison of Carbon Offset Standards' (Stockholm Environment Institute and Tricorona, March 2008), https://www.globalcarbonproject.org/global/pdf/WWF_2008_A%20comparison%20of%20C%20offset%20Standards.pdf; UNFCCC, 'CDM Project Cycle', UNFCCC - Clean Development Mechanism (CDM), 2023, https://cdm.unfccc.int/Projects/diagram.html; UNFCCC, 'Designated National Authorities', UNFCCC - Clean Development Mechanism (CDM), 2023, https://cdm.unfccc.int/DNA/index.html.

[101] UNFCCC, 'CDM Methodology Booklet Fourteenth Edition' (United Nations Framework Convention on Climate Change, December 2022), https://cdm.unfccc.int/methodologies/documentation/2303/230426_BLS23047_CDM_booklet_v04.pdf; UNFCCC, 'Materiality Standard under the Clean Development Mechanism', UNFCCC - Clean Development Mechanism (CDM), 2023, https://cdm.unfccc.int/about/materiality/index.html.

[102] UNFCCC, 'CDM Project Cycle'; UNFCCC, 'Designated National Authorities'.

[103] UNFCCC, 'CDM Project Cycle'.

[104] UNFCCC.

[105] UNFCCC.

[106] UNDP, 'Chapter 6: CDM Transactions: A Review of Options', in *The Clean Development Mechanism: A User's Guide* (New York, NY: United Nations Development Programme, 2015), 69–74, https://www.undp.org/sites/g/files/zskgke326/files/publications/cdmchapter6.pdf.

[107] GS, 'Governance', Gold Standard - About Us, 2023, https://www.goldstandard.org/about-us/governance.

Board and supported by an NGO Supporter Network, as well as technical committees and working groups[108]. Roughly two-thirds of GS's funding comes from certification income, i.e., registration fees, issuance fees, registry fees, VVB accreditation fees, and similar, while the remaining third is grant funding from, e.g., Germany[109].

GS also has historically close ties to the CDM. It has been around since the CDM was first designed and was initially devised as a complementary scheme, providing additional quality labels for CERs, before eventually becoming its' own fully fletched, Verified Emissions Reductions (VERs)-issuing mechanism[110]. Aside from providing additional quality labels for CERs, GS's project cycle mirrors the CDM, and it even allows CDM projects to fully transition over if certain criteria are met, i.e., projects can switch regulatory regime ex-post, opening a secondary sorting option to developers.

Should a CDM project choose to do so, they must send all their remaining CERs to GS's CDM account, which voluntarily retire them, while they in turn receive VERs on the GS registry, in a one-for-one exchange[111]. This is distinct from the fact that transitioning projects will be re-evaluated by GS at entry, which is where the estimated annual reductions can potentially be re-determined[112]. Lastly, to be eligible to work for GS, VVBs must either be accredited by the CDM, by an International Accreditation Forum member body for ISO14605 scope or be a certification body themselves[113].

Differences between GS and the CDM are numerous, only a selection can be discussed here. On a strategic level, GS sets itself apart from other offsetting mechanisms by putting co-benefits into the spotlight, thereby emphasizing involvement of local populations, e.g., via extensive consultations, and the natural environment[114]. DNA-related steps from the CDM are of course absent at GS, projects may be situated

[108] GS.
[109] GS, 'FAQs', Gold Standard - Frequently Asked Questions, 2023, https://www.goldstandard.org/resources/faqs; GS, 'Fee Schedule', Gold Standard - Fee Schedule, 2023, https://globalgoals.goldstandard.org/fees/; GS, 'Fee Schedule - VVB', Gold Standard for the Global Goals, 2023, https://globalgoals.goldstandard.org/fee-schedule-vvb/.
[110] GS, 'FAQs'.
[111] GS, 'GHG Emissions Reductions and Sequestration Product Requirements' (Gold Standard, 24 February 2022), https://globalgoals.goldstandard.org/501-pr-ghg-emissions-reductions-sequestration/; GS, 'FAQs'; GS and WWF, 'The Gold Standard:Quality Standards' (WWF, October 2002), https://www.wwf.or.jp/activities/lib/pdf_climate/gold-standard/COP8_standards.pdf.
[112] GS, 'FAQs'.
[113] GS, 'Validation/Verification Body Requirements' (Gold Standard, 14 February 2021), https://globalgoals.goldstandard.org/109-par-validation-verification-body-requirements/.
[114] GS, 'Gold Standard for the Global Goals - Principles and Requirements, Version 1.2' (Gold Standard, October 2019), https://globalgoals.goldstandard.org/101-par-principles-requirements/; GS, 'Safeguarding Principles & Requirements' (Gold Standard, October 2019), https://globalgoals.goldstandard.org/103-par-safeguarding-principles-requirements/; GS, 'Stakeholder Consultation and Engagement Requirements' (Gold Standard, 14 June 2022), https://globalgoals.goldstandard.org/102-par-stakeholder-consultation-requirements/; GS, 'FAQs'.

in industrialised host countries, developers can utilize GS's own methodologies, and the demand side consists primarily of private actors, rather than nation-states[115].

As for the project cycle, activities need to pass an auxiliary "announcement" test for additionality[116], new methodologies are reviewed by independent experts before they are vetted by a Technical Advisory Committee (TAC), and only a subset of the projects eligible for the CDM are eligible at GS too[117]. At the validation and verification report review stages, projects are vetted by the GS Secretariat, the TAC, and multiple NGO supporters; bottom-up initiated reviews are welcomed for all aspects of the issuance cycle and projects are automatically required to re-verify every five years[118].

Moving to the second VCM, Verra is a non-profit corporation registered in Washington DC, which was founded by environmental and business leaders in 2007; it is, historically, more distinct from the CDM than GS[119]. It also differs from the two previous cases in institutional structure: There is no "Secretariat", just operations and a "Board of Directors" that oversees and develops strategies, much alike a for-profit company[120]. There are, however, "Advisory Groups and Committees" with specialized expertise to rely on within Verra, which are cross-sectoral and multi-stakeholder arrangements[121].

Like GS, Verra also relies on fees and commissions as main revenue source, demanding payment from developers relative to the crediting amount sought, an issuance levy, and other fees, e.g., for VVBs to partake[122]. Verra also certifies co-benefits of external projects, though these products are kept separate from the carbon crediting program, which issues Verified Carbon Units (VCUs)[123]. The project cycle mirrors the CDM, though projects can request initial validation and verification in a single action, if implementation and monitoring have already been done adequately[124]. Verra also allows CDM projects to transition over; again, one-for-one credit conversion and re-evaluation at entry is upheld[125].

[115] GS, 'FAQs'.
[116] The "announcement test" checks whether the activity was already announced before crediting was secured.
[117] GS, 'Safeguarding Principles & Requirements'; GS, 'Stakeholder Consultation and Engagement Requirements'; GS, 'FAQs'; Kollmus, Zink, and Polycarp, 'Making Sense of the Voluntary Carbon Market: A Comparison of Carbon Offset Standards'.
[118] GS, 'Gold Standard for the Global Goals - Principles and Requirements, Version 1.2'; GS, 'Standards Setting Procedures' (Gold Standard, 9 April 2021), https://globalgoals.goldstandard.org/000-1-gov-standards-setting-procedure/; GS, 'NGO Supporters', Gold Standard - NGO Supporters, 2023, https://www.goldstandard.org/about-us/ngo-supporters.
[119] Verra, 'Who We Are', Verra - About, 2023, https://verra.org/about/overview/#overview.
[120] Verra, 'Board of Directors', Verra - About, 2023, https://verra.org/about/board-of-directors/.
[121] Verra, 'Advisory Groups & Committees', Verra - About, 2023, https://verra.org/about/overview/advisory-groups-committees/#.
[122] Verra, 'Program Fee Schedule' (Verra - VCS, 17 January 2023), https://verra.org/wp-content/uploads/2022/12/Program-Fee-Schedule-v4.2-OFFICIAL-Q4-2022-FINAL.pdf.
[123] Verra, 'Program Details', Verra - Resources, 2023, https://verra.org/programs/program-details/.
[124] Verra, 'Registration and Issuance Process' (Verra - VCS, 17 February 2023), https://verra.org/wp-content/uploads/2022/12/VCS-Registration-and-Issuance-Process-v4.3-FINAL.pdf.
[125] Verra.

Differences, relative to the CDM, are less numerous and additional safety measures are less explicit and institutionalized at Verra than at GS. There are, e.g., no stakeholder consultations to the extent that GS does them, it rather allows for a 30 day commenting period during validation to passively gauge local stakeholder interests[126]. There is also no review by technical committees and associated NGOs at validation and verification[127]. Notably, Verra and the CDM – aside from the key difference of interest here – are thus more alike than GS and the CDM.

The link to non-featured VCMs is more pronounced at Verra than at GS: It allows usage of methodologies that were developed by the Climate Action Reserve (CAR), another VCM, and enables transitioning of projects into the VCU system from other VCMs too[128]. There is, distinct from the regular project cycle, a wholly separate quality control mechanism engaging in project review at Verra; these reviews can be initiated either by the VVB, the project proponent, a stakeholder, or Verra itself, should they suspect wrongdoing[129]. Verra upholds the same VVB requirements as GS[130].

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[126] Verra.
[127] Verra.
[128] Verra, 'FAQs', Verra - Frequently Asked Questions, 2023, https://verra.org/programs/verified-carbon-standard/vcs-program-details/vcs-frequently-asked-questions/; Verra, 'Registration and Issuance Process'.
[129] Verra, 'Registration and Issuance Process'.
[130] Verra, 'Validation and Verification', Verra - Verified Carbon Standard, 2023, https://verra.org/validation-verification/#for-the-vcs-program.

Descriptive results

The following section discusses key data characteristics descriptively. The core dataset contains 8.842 non-transitioned, post-2009 registered projects: 5.812 in the CDM, 1.347 at Verra, and 1.683 at GS. The general sample is thus distributed unevenly, with almost two-thirds of observations in the CDM. 3.896 had been issued credits before, though intra-registry shares vary: Only 34 percent of CDM projects had issued credits before, while this value was 75 percent for Verra, and 56 percent for GS.

At Verra, only one project made use of the option to apply a CAR methodology, while 83 percent relied on a CDM methodology. 78 percent of Verra observations used a VVB that was accredited with the CDM beforehand, though 19 percent used one that later withdrew or whose registration expired at the CDM. At GS, 47 percent of projects used a CDM methodology, with the rest relying on GS's self-developed alternatives. The GS registry also distinguishes between stand-alone and programme activities: 62 percent of all activities were registered as addition to a pre-existent programme.

Further differences are visible, e.g., for the temporal dimension of registration. CDM registration numbers grew substantially from 2009 to 2012, peaking at 2.994 in the latter year, before dropping back down in equally striking fashion. Since the start of 2021, only one new project has been registered in the CDM. As expected, the two VCMs follow an inverse trajectory to these trends and exhibit less volatility in absolute terms. Both encountered comparatively low registration numbers early on.

For Verra, annual registrations stayed below 60 new projects up until 2019, before rocketing up to 686 in 2020 alone; the recent spike in VCM interest was clearly visible. GS, on the other hand, experienced growth earlier, repeatedly recording over 100 registrations per year in the early 2010s. Nevertheless, and similar to Verra, GS too experienced a clear uptick in registrations more recently, exceeding 200 a year for the first time in 2021 and hitting this milestone again in 2022. First credit issuance dates are more evenly spread than registration dates, but still mirror their general trends.

Project characteristics reveal further divergence. CDM activities are split circa 60-40 between large- and small-scale, while renewable energy[131] is by far the most prominent

[131] Categories are based on UNEP DTU classification, which was further collapsed into Biomass energy, Energy efficiency households, Energy efficiency industry, Energy efficiency other, Fuel/feedstock switch, Fugitive emissions, Hydro energy, LFG/methane capture and utilization, Methane avoidance, Nature-based solutions, Renewable energy other, Solar energy, and Wind energy. For more information, please see section "Project type classifications" in the Annex.

project type. “Wind energy” alone already makes up more than a third of CDM observations. At Verra, observations are essentially distributed 50-50 between large- and small-scale and types are more balanced: “Wind energy” is still dominant (19,6 percent), but closely followed by “Nature-based solutions”[132] (19,1 percent). For GS, projects are usually small-scale (80 percent) and focus on “Energy efficiency of households” (59 percent), followed by “Methane avoidance” (11 percent).

In terms of geographic distribution, a clear break between the CDM and the two VCMs manifested as well. Around two-thirds of all registered CDM projects are situated in East Asia and Pacific[133], followed by South Asia (18 percent), and Latin America and Caribbean (10 percent); no project was undertaken in North America, in line with eligibility criteria. Followingly, 95 percent of CDM observations were hosted middle-income nations, while less than one percent was situated in Low income nations, casting doubt over developmental ambition, though this is a 2023 classification.

At Verra, South Asia dominated (28 percent), with East Asia and Pacific second (22 percent), and Latin America and Caribbean third (17 percent). Around 5 percent of Verra observations were in low-income countries, while 80 percent were to be found in middle-income nations. GS stood out in that over half of its’ projects were in Sub-Saharan Africa (51 percent), followed by East Asia and Pacific alongside South Asia (both 16 percent). Relatedly, 38 percent of registered GS projects were situated in low-income economies, the dominant category.

The transitioned sub-sample, on the other hand, contains 883 individual projects. A small minority (11 obs.) of which not only switched from the CDM to a VCM, but then also between the two VCMs covered. Consequently, 654 projects moved to Verra and 241 to GS. CDM registration date information revealed that the largest share of moving projects was first registered there in 2012 (27 percent), followed by 2009 (14 percent), 2010 (13 percent), 2011 (13 percent), and 2008 (12 percent).

45 percent of projects that moved away were hosted in East Asia and Pacific, with another 44 percent located in South Asia. The most dominant project type among transitioned projects was “Wind energy” (42 percent), followed by “Hydro energy” (18 percent), “Methane avoidance activities” (9 percent), “Solar energy”, and “Biomass

[132] For an overview of project type classifications please see section “Project type classification” in the Annex.
[133] Categories are based on the latest World Bank classification and include East Asia and Pacific, Europe and Central Asia, Latin America and Caribbean, Middle East and North Africa, North America, South Asia, and Sub-Saharan Africa for the regions. Income groups are split into low-income, lower middle-income, upper middle-income, and high-income economies. For more information, please see Annex.

energy” (7 percent each). Around 58 percent of transitioned projects were classified as large-scale.

As for the key outcome variable covered here, i.e., estimated annual emissions reductions in mtCO2e per project, this primary and secondary sorting seemingly led to stark inter-mechanism differences (Table 2).

The over-representation of small-scale projects in GS, e.g., pulls down its’ overall average estimated annual emissions reductions, while Verra – on average – credits the largest amounts overall. Projects that had already issued credits before were only under-credited, relative to the full sample, at GS. GS and the CDM both have higher average estimated reductions for higher income countries, while Verra exhibits an inverse pattern. Verra also produced the highest average estimates for small-scale projects[134], while the CDM and GS are in close proximity for such projects; a similar pattern can be observed for large-scale projects post-2009.

Project types were further binned into “Renewable energy”, “Other technological”, and ”Nature-based solutions” for this analysis. The core intuition for this is that “Renewable energy” is the category with which BAC systems have the most experience and such projects also produce – similar to “Other technological” – mitigation that is more easily measurable and quantifiable than, e.g., for “Nature-based solutions”. Interpretability of results is limited due to inter-registry project sorting but – once more – Verra exhibits by far the largest average estimates.

As for the transitioned sub-sample, re-evaluation at entry did not result in a different estimated annual emissions amount for 69 percent of projects moving to Verra and 59 percent of projects moving to GS. The novel assessment at the time of transition only thus only leads to a different estimated reduction amount for the minority of observations. On average, transitioning into Verra led to a decrease in estimated annual emissions reductions by 7.225 mtCO2e; the same figure stands at 1.956 mtCO2e for GS. However, this descriptive analysis does not control for project fundamentals and consequently has to be interpreted with great caution.

[134] Note that this variable was harmonized using the respective project methodology; in other words, if the project was using a methodology that was classified as small-scale methodology, this was transposed to the project. For more information, please see Annex.

Table 2 – Selected descriptive statistics

Descriptive	CDM pre-2009 (1.145 obs.)	CDM post-2009 (5.812 obs.)	Verra (1.347 obs.)	GS post-2009 (1.683 obs.)
Avg. reductions, all registered projects	198.189	115.866	207.178	58.887
Avg. reductions, post-verification projects	234.179 (904 obs.)	152.529 (1.947 obs.)	213.976 (1.006 obs.)	54.909 (943 obs.)[135]
Avg. reductions, low-/lower middle-income	67.600 (421 obs.)	88.492 (1.669 obs.)	375.177 (555 obs.)	56.040 (1.219 obs.)
Avg. reductions, upper middle-/high-income	285.481 (724 obs.)	103.720 (4.143 obs.)	153.422 (792 obs.)	80.331 (458 obs.)
Avg. reductions, small-scale projects	27.371 (515 obs.)	24.308 (2.259 obs.)	99.807 (676 obs.)	28.562 (1.343 obs.)
Avg. reductions, large-scale projects	337.826 (630 obs.)	174.078 (3.553 obs.)	315.621 (671 obs.)	178.670 (340 obs.)
Avg. reductions, renewable energy projects	77.879 (396 obs.)	108.011 (4.053 obs.)	159.451 (560 obs.)	105.067 (367 obs.)
Avg. reductions, other technological projects	262.113 (748 obs.)	137.623 (1.701 obs.)	159.739 (530 obs.)	46.738 (1.284 obs.)
Avg. reductions, nature-based solutions	25.795 (1 obs.)	26.723 (58 obs.)	409.716 (257 obs.)	16.718 (32 obs.)
Transitioned projects, count	-	-	653	241
Transitioned projects, no change share	-	-	69%	59%
Transitioned projects, average difference	-	-	-7.225	-1.956

[135] Observations in across all income groups taken together do not sum to 1.683, but 1.677, for GS as six projects were classified as "International" (e.g., energy efficiency in maritime transport).

Regression results

Moving on to regression analysis, all multivariate OLS results can be found in Table 3 below. Across all models, the intercept captures the average effect of being a large-scale "Biomass energy" project situated in East Asia and Pacific that registered between 2009-2013 and had not issued any credits at the time of writing; for the final specification, in column (5), the intercept additionally captures the effect of being registered with the CDM instead of either VCM. All coefficients need to be interpreted relative to this baseline.

In derivation of the fully specified model discussed in the "Methods" chapter, within-registry regressions, and a full sample regression dummy, were run without inclusion of the VCM dummy. Adjusted R-squared results are comparatively low throughout, which is broadly in line with the substantial project heterogeneity on offset markets discussed previously. Note that, as both VCMs featured projects in North America, which the CDM did not, such observations had to be left out of the inter-registry specifications due to collinearity, cutting the sample to 8.730 pure observations.

Column (1), then, contains all CDM observations post-2009 that did not transition; the majority of independent variables in this model is statistically significant at the five percent level, at a minimum. Relative to baseline, projects classified as "Renewable energy other" had the largest surplus, on average yielding 143.220 more mtCO2e in estimated reductions than "Biomass energy". Nature-based solutions performed relatively worst in the CDM, yielding 86.156 mtCO2e less than the baseline project, on average and holding all other explanatories constant.

As expected, small scale projects have significantly less climate potency, while regional effects were only significant for South Asia and Sub-Saharan Africa, where both exceeded average reductions for East Asia and Pacific for the baseline project, ceteris paribus. There also seems to have been a statistically significant drop of estimated reductions in the five-year period following 2009-2013, at the one percent level, whereas the final five-year period exhibited relatively higher reductions than baseline, at the five percent level. Projects that had already issued credits exhibited, on average, significantly higher reductions on the CDM.

As for the pure Verra projects in column (2), the only reasonably significant explanatories were the intercept, the Energy efficiency households, Energy efficiency other, and Nature-based solution categories, the project size, and the regional coefficients for Europe and Central Asia, South Asia, and Sub-Saharan Africa. Crucially, the core specification – which contains plenty of indicators that are not just ex-ante powerful but also statistically and economically significant throughout for the CDM – seemingly offers less explanatory potency for Verra.

There seemingly are other key determinants at play when emissions reductions are estimated in the Verra system. For this application, the model thus seemingly suffers from omitted variable bias, though given the careful selection of explanatories to reflect key fundamentals in ex-ante project potency, this does not put Verra in a good light. At GS, which is featured in column (3), relatively more of the independent variables were statistically significant at a reasonable level, though the amount of significant coefficients still falls noticeably short of the CDM model.

Absolute effect sizes are hard to compare between the intra-registry regressions in columns (1) to (3), as the models seemingly carry highly variant explanatory power. This bars rigorous comparison of the CDM against the two VCMs using simply intra-registry estimations. Still, with conservativeness in mind, one can compare the effect signs of significant outcomes to get an idea of how within-registry estimation might differ. Relative to the baseline case, “Nature-based solutions” are, e.g., more climate-potent at Verra, clearly contradicting CDM results. An inverse pattern holds for the regional effects of Europe and Central Asia.

Aside from the region coefficients for the latter, alongside Middle East and North Africa, GS results are not only more significant throughout, but also more aligned with the CDM. The “Nature-based solutions” category, e.g., has the same, negative sign as for the CDM. The model, which was developed and harmonized using the CDM as base, also yields the highest adjusted R-squared for GS among all samples, indicating that emission reduction estimation is most fundamentals-aligned at GS. As for the issuance dummy, both Verra’s and GS’s coefficient is insignificant, but negative, while the CDM exhibits a positive as well as statistically and economically significant outcome.

Moving on to the full sample, in columns (4) and (5), the explanatory power of both is thus likely driven by CDM and – to some extent – GS observations. “Fuel/feedstock switch” projects were seemingly most climate-potent, followed by “Nature-based solutions”, in the inter-registry sample, on average and controlling for all other explanatories. “Wind energy” endeavours, on the other hand, had the lowest estimated annual emissions reductions, relative to baseline. Keeping all other indicators constant, small-scale projects achieved – on average – around 200.000 mtCO2e less estimated reductions than large-scale ones.

Compared to East Asia and Pacific, projects hosted in Europe and Central Asia possessed lower estimated reductions, while those in Sub-Saharan Africa and – especially – in South Asia were granted more reductions, on average. There has further been a statistically significant uptick in emissions reductions in the last five years, and projects that had a first issuance date were deemed more climate potent overall, ceteris paribus. Inclusion of the VCM dummy in column (5) did not alter these results noticeably. The dummy itself is not statistically significant at any reasonable level and economically negligible.

Table 3 – Multivariate regression results

	(1) CDM post-2009, pure		**(2) Verra, pure**		**(3) GS post-2009, pure**		**(4) All pure observations**		**(5) All pure obs. + dummy**	
	Coeff.	**t-stat**	**Coeff.**	**t-stat**	**Coeff.**	**t-stat**	**Coeff.**	**t-stat**	**Coeff.**	**t-stat**
Intercept	146.725,81 ***	11,86	202.291,34 *	2,50	213.741,60 ***	8,99	160.251,22 ***	11,58	160.032,23 ***	11,56
Biomass energy	Baseline		Baseline		Baseline		Baseline		Baseline	
Energy efficiency households	15.851,26	0,48	361.582,53 ***	4,27	-21.221,36	-1,01	23.407,94	1,28	22.290,70	1,20
Energy efficiency industry	-7869,25	-0,44	83.335,28	0,77	-7.690,86	-0,17	-5.426,81	-0,26	-5.066,289	-0,25
Energy efficiency other	168.370,44 ***	7,31	182.102,85 .	1,74	-51.916,92	-1,40	131.717,80 ***	5,26	131.919,03 ***	5,26
Fuel/feedstock switch	365.964,27 ***	12,56	28.637,60	0,24	-		283.305,94 ***	8,77	283.467,77 ***	8,77
Fugitive emissions	104.187,11 ***	4,34	162.233,74	1,03	-		111.645,19 ***	4,02	112.317,95 ***	4,03
Hydro energy	49.047,11 ***	3,78	123.320,72	1,60	-28.906,32	-1,12	54.492,72 ***	3,76	54.878,81 ***	3,78
LFG/methane capture and utilization	33.247,94 .	1,92	9.523,56	0,12	4.4833,48	1,10	20.708,35	1,09	21.029,05	1,11
Methane avoidance	32.446,80 .	1,95	93.776,61	1,13	-1.0567,82	-0,48	39.724,51 *	2,34	39.198,52 *	2,30
Nature-based solutions	-86.156,33 **	-2,71	319.872,94 ***	4,27	-51.317,76 .	-1,73	200.532,44 ***	9,51	199.793,28 ***	9,44
Renewable energy other	143.129,88 ***	3,50	62.670,98	0,42	80.630,50	1,93	112.988,93 **	2,90	112.857,10 **	2,90
Solar energy	-38.245,22 *	-2,31	89.183,21	1,05	-8.894,01	-0,38	-8.912,21	-0,51	-8.808,12	-0,50
Wind energy	-43.443,03 ***	-3,38	-31.402,19	-0,45	-42.516,70 .	-1,76	-48.171,93 ***	-3,38	-47.953,94 ***	-3,36
Large-scale	Baseline		Baseline		Baseline		Baseline		Baseline	
Small-scale	-170.498,42 ***	-23,06	-294.983,74 ***	-9,34	-171.657,34 ***	-18,35	-200.262,45 ***	-26,88	-200.377,50 ***	-26,87
East Asia & Pacific	Baseline		Baseline		Baseline		Baseline		Baseline	
Europe & Central Asia	56.723,06 .	1,89	-119.347,01 *	-2,35	-38.344,88 **	-2,90	-52.061,32 ***	-3,61	-53.993,26 ***	-3,52
Latin America & Caribbean	12.450,96	1,23	-34.032,63	-0,72	-7.571,50	-0,47	-3.863,11	-0,36	-3.912,78	-0,37
Middle East & North Africa	-3.674,64	-0,17	-108.616,99	-0,66	111.982,15 .	1,86	-8,01	0,00	368,88	0,014
North America	-		-32.179,62	-0,53	41.058,67	0,59	-		-	
South Asia	51.177,41 ***	5,52	86.118,82 .	1,76	46.862,90 ***	4,15	61.089,08 ***	6,59	60.910,85 ***	6,57
Sub-Saharan Africa	66.671,48 ***	3,31	142.060,40 *	2,46	12.108,29	1,05	33.703,10 *	2,43	33.447,46 *	2,41
2009-2013	Baseline		Baseline		Baseline		Baseline		Baseline	
2014-2018	-30.428,69 *	-2,17	30.175,09	0,50	-17.123,34 .	-1,92	-11.120,27	-1,03	-13.135,52	-1,09
2019-2023 (as of April 26, 2023)	76.990,78 .	1,81	24.283,21	0,55	8.431,11	0,88	51.059,79 ***	5,36	47.909,10 ***	3,77
Only post-validation	Baseline		Baseline		Baseline		Baseline		Baseline	
Also post-verification	38.816,17 ***	6,23	-7.175,23	-0,22	-8.266,93	-1,31	28.091,69 ***	4,53	27.610,54 ***	4,36
Registered with the CDM									Baseline	
Registered with a VCM									4.625,25	0,38
Sample size	5.812		1.347		1.683		8.730		8.730	
Multiple R-squared	0,170		0,128		0,250		0,133		0,133	
Adjusted R-squared	0,167		0,113		0,241		0,131		0,131	
F-statistic	56,46 ***		8,791 ***		27,54 ***		63,43 ***		60,55 ***	

Significance codes: 0 `***´, 0,001 `**´, 0,01 `*´, 0,05 `.´, other ` ´

Discussion

Linking results back to PAT theory allows one to develop an answer to the research question. Given initial qualitative comparison, it is – already a priori – disputable how much more stringent private regulatory regimes can be if they not only use the same third-party monitors and project cycle as the CDM, but also widely rely on the same methodologies and procedures to manage contractual relations. And not only are many organizational aspects copied from the CDM, VCMs add on top of this an additional layer of incentive malignment: Standard setters' fee schedules and levy systems directly relate to the crediting amount and demand repeat fees from the VVBs too, despite both gatekeepers' reliance on the developers as main income source.

By relying exclusively on project developers in revenue generation, the principal's interests are aligning with the agent's, rather than the other way around. Reputational constraints related to environmental agency costs are superseded by economic considerations. And given the agent is prone to moral hazard and can – due to its' substantial discretion when sorting into regulatory regimes – readily engage in adverse selection, this can reasonably be expected to yield inflationary tendencies overall. Consequently, and as Battocletti et al. (2023) and other papers have already pointed out, it is likely that key supply-side participants in the VCMs share a common interest: Increasing estimated emission reductions.

Descriptive results provided some empirical evidence for this suspicion. Given that the CDM has been extensively criticized for its' insufficient environmental integrity, it was already a fairly notable finding that both Verra and GS allow for CDM project transition into their regimes at all. And evidence suggested that this has indeed caused several environmental integrity tensions. It has been documented that the CDM's insufficiencies were relatively more considerable during its' first years of existence, before major reforms were made[136]. It follows from this that VCMs should – at the very least – only allow later projects to transition if they are in fact more stringent overall.

Yet, among the projects that had moved over, some were first registered by the CDM as far back as 2005. Moreover, the CDM registration period 2005-2012 contained no less than 88 percent of all transitioned projects, casting plenty of doubt over transition

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[136] e.g., Kainou Kazunari, 'Collapse of the Clean Development Mechanism Scheme under the Kyoto Protocol and Its Spillover: Consequences of Carbon Panic', *VOXEU Column - Environment* (blog), 16 February 2022, https://cepr.org/voxeu/columns/collapse-clean-development-mechanism-scheme-under-kyoto-protocol-and-its-spillover.

eligibility criteria of VCMs from a stringency standpoint. On average, 67 percent of transitioned projects also entered VCMs with the same estimated reductions as they had in the CDM, despite re-evaluation at entry. They were also predominantly large-scale and of technological nature which puts the premise that activities move, e.g., for co-benefit certification reasons, into doubt. These findings do not align well with the idea that VCMs add stringency in crediting, relative to the CDM.

Moving on, while the primary sorting of projects into registries hinders causal interpretation of regression results, several of the uncovered associations are worth highlighting, nevertheless. Holmström (1979), e.g., suggests that repeat contact between the principal and the agent usually allows the former to circumvent information asymmetry better; in the credit issuance case, it could thus be argued that projects which made it not only through validation but also through verification should thus be – on average – less-affected by asymmetry constraints.

If one assumes that projects start off with inflated baselines and are gradually filtered and vetted, it would be expected that estimated reduction amounts are lower in the sub-group that made it to issuance, ceteris paribus. However, the CDM's, as well as the full model's respective coefficient is positive and statistically significant, with VCMs' estimates being insignificant and slightly negative. It seems that neither the CDM nor the VCMs are measurably sorting out projects with disproportionately high estimations before credit issuance, despite having engaged in quality assurance twice before.

Other individual coefficients suggest that the GS – in a general sense – is closer in terms of outcomes to the CDM than Verra, given they shared many significant coefficients. Further, project types that are notoriously hard to measure accurately, e.g., "Nature-based solutions", were heavily over-credited at Verra, all else equal. Nonetheless, it shall be noted that both VCMs' intra-registry regressions yielded fewer significant coefficients than the CDM. Aside from individual explanatory's value, it could thus be argued that reduction estimations are less fundamentals-based on VCMs than for the CDM, with Verra performing worse than GS.

Here, the idea that crediting stringency on the intensive margin might vary by crediting regime was explored and, overall, the identification strategy of qualitative comparison, quantitative descriptives, and regression results yielded plenty of useful insights into the relation between the three cases considered. For the purpose of answering it, it is meaningful to re-consider the original research question posed by this thesis:

Are VCMs more stringent in crediting than the CDM?”

While regression results require non-causal interpretation given specification caveats, the final model perhaps summarizes the answer uncovered here best: Being situated on a VCM is not associated with a significantly higher or lower amount of annual estimated emissions reductions, ceteris paribus. VCMs, as a summed category, are neither detectably superior nor inferior to the CDM in terms of crediting conservativeness. Hence, they do not add statistically significant and economically relevant amounts of crediting stringency relative to the CDM, neither do they perform significantly worse.

Throughout analysis, it has also become evident that Verra is relatively closer to the CDM, while GS is more explicit in providing additional safety measures. The selection premise, i.e., to find cases that are equal to the CDM in all regards except for the fact that they are fully private, is arguably truer for Verra. Summing both VCMs into one category might bias results against GS, which is nicely underlined by intra-registry descriptives and regression findings. Notably, this points to the dichotomy of compliance versus voluntary markets not being useful: VCMs are not homogenous.

Further research would be well advised to look into sorting motives of developers, as perhaps the most important integrity outcome determinant. It would also be meaningful to explore the dataset created for this thesis in more detail, potentially allowing not only for a VCM dummy, but a categorical variable that differentiates between different VCMs when comparing them relative to the CDM in regression. Equally, the extensive margin of credit issuance on VCMs, i.e., the decision that projects are eligible in the first place, could use further unpacking.

Conclusion

Global climate governance is a dynamic matter, constantly evolving and increasing in complexity. VCMs are but one example of this in practice. However, they are hardly novelties themselves, as the baseline-and-credit (BAC) system they rely on has been applied by several compliance mechanisms before, commonly with unsatisfactory results. Caution is warranted when ineffective ideas are being re-packaged, especially if knowledge on how this re-packaging affects outcomes is minimal. This thesis assists in filling this research gap, by contrasting VCMs to the – arguably dysfunctional – CDM.

Results suggested that both Verra and GS are closely related to the CDM baseline, despite claiming to be superior regulatory regimes in terms of rigour. They rely on CDM methodologies, employ similar third-party VVBs, use analogous project cycles, and even allow CDM projects to transition into their systems, all without adding much additional stringency. Further, descriptive statistics revealed that project developers are not randomly picking their regulator. Rather, sorting patterns emerge that can reasonably be interpreted as a sign of adverse selection, in line with theory[137].

In multivariate regression, which controlled for key project characteristics, it was further evident that VCMs' climate potency assessments are less fundamentals-based than the CDM's. Regression-specific findings went both ways: Some pointed toward Verra and GS being an improvement over the CDM, others, such as the substantial over-crediting of NbS projects by Verra, painted an opposing picture. The final model suggested that – relative to the CDM – the grouping of Verra and GS was neither more conservative nor more incautious in granting estimated annual emissions reductions.

Positing that VCMs are inherently superior to the CDM is thus imprudent. While some of their governance parameters certainly promise better outcomes, e.g., the additional effort they make to enable wider SDG achievement, the core mechanism they employ bears downsides that cannot be removed, even in an ideal-type scenario. Principal-agent tensions, the net-neutral nature of offsetting, and other restrictions around central environmental integrity criteria make carbon crediting, at best, a secondary tool to rely on in sound climate policymaking.

[137] e.g., James Bushnell, 'Adverse Selection and Emissions Offsets', *Energy Institute at Haas*, Energy Institute at Haas - Working Papers, 222 (2011): 28.

ANNEX

Please note that the following appendix contains only part of additional, available information about this thesis. A separate Online Annex contains all raw data, interim data and coding files, as well as final outputs. The Online Annex enables re-construction of all results featured in the analytical sections of this thesis from scratch. Notably, the statistical programming files also feature additional information on the "Data preparation" section featured here, which were not included for length reasons.

Data preparation

- *CDM*

As the CDM served as baseline in harmonization, little had to be done to enable comparison. The project-level download did not feature VVB and other information that was required and available in a different dataset, downloadable on the same website via the link "Database for PAs and PoAs". This additional information was merged into the project-level data. No further preparatory steps were needed.

- *Verra*

For Verra, multiple steps had to made to enable comparability. First, the raw project-level download did not feature issuance information, These datapoints were available in a separate dataset, tracking transactions, which was available on the same website as the project-level data by specifying the search differently. Issuance data was then merged into the project-level dataset.

Second, Verra did not feature VVB information, which had to be web-scraped using Python. No missing values were created doing this as registered projects, by definition, have to have an assigned VVB. Third, Verra does not adhere to the UNEP DTU project type classification, neither does it provide project sizes. To harmonize the dataset in this regard, the fact that Verra mostly uses CDM methodologies was made use of: With the help of the CDM methodology booklet, Verra projects were classified in types and size.

While this is of course an assumption, it could be argued that deviation from the booklet potentially represents usage of the wrong methodology for a given project. Sizes were transposed without any alteration while project types were double-checked using project titles for all observations, as methodologies are always clear on project sizes but sometimes ambiguous regarding project types.

The third step also resulted in some minor re-classifications relative to the CDM: When projects were obviously of “Fossil fuel switch”, “Methane avoidance”, or “Coal bed/mine methane” kind, but the methodology binned them differently, they were re-categorized. When renewable energy projects were not classified to sufficient detail; i,e,, when methodologies only said renewable energy (e,g,, AMS-I.D.); the latter instances were further divided up. In rare cases, project website were consulted to rid uncertainty.

Projects that did not utilize a CDM methodology were evaluated methodology-by-methodology or, if necessary, case-by-case, and classified using all available information for them, such as the project title, the sector, and the website. The same was done for such that did not have a listed methodology (26 observations). In addition, “Afforestation” projects, which include all nature-based solutions in this analysis, did not have an immediately obvious size, as methodologies are generally ambiguous regarding them.

For these, information about hectares covered by the project was web-scraped, the median was taken, and the bottom half was classified as small, while the top half was classified as large. In sum, Verra data cleaning and processing provided a great level of detail while retaining a conservative approach,

- *Gold Standard (GS)*

For GS, another sequence of steps was required. First, “Listed” projects which were before-registration were dropped, alongside observations without emissions reductions, such as micro-credit endeavours. The project type category already followed the UNEP DTU classification, broadly speaking. Small adjustments were made to formatting, only rather inconsequential decisions had to be made, in line with other available information, like the project title. Duplicates and project conversions were identified manually and dropped accordingly.

Registration dates are not featured in the baseline download and had to be reconstructed for each case, one-by-one, using project documentation available on the respective activity’s SustainCert page. When there was a GS validation report, the date of the final draft was taken as registration date. If this was not available, the issuance date of the last GS PDD was taken as proxy, cross-checked with any monitoring reports if applicable. Eight observations had not online documents, these were entered with the same registration year as the project with the next higher ID. Dates were then merged in. The size categorization was harmonized to Small-Large.

Project type classifications

The following table contains ex-post classification type categorizations. This step was done taking into consideration what type of mitigation activity is dominant in each UNEP DTU class; e.g., “Landfill gas” and “Coal bed/mine methane both capture methane and utilize it for heat or energy generation, whereas “Methane avoidance” destructs the gas instead of making further use of it. “Agriculture” was the only category that had to be split case-by-case; if an “Agriculture” project contained energy efficiency endeavours, such as installation of a new irrigation system, it was classified as “Energy efficiency other”. If the project was however primarily engaged in biological sequestration, “Agriculture” was harmonized into “Nature-based solutions”, which serves as the overall bin for carbon sink projects.

Table 4 - Project type classifications

UNEP DTU classification (as applied by the CDM)	**Primary type collapse** (as featured in regression)	**Secondary type collapse** (as featured in descriptives)
Hydro energy	Hydro energy	Renewable energy
Solar energy	Solar energy	
Wind energy	Wind energy	
Geothermal energy	Renewable energy other	
Tidal energy		
Mixed renewables		
Biomass energy	Biomass energy	Other technological
Energy efficiency households	Energy efficiency households	
Energy efficiency industry	Energy efficiency industry	
Energy efficiency own generation		
Energy efficiency service	Energy efficiency other	
Energy efficiency supply-side		
Transport		

Energy distribution		
Agriculture*		
Fossil fuel switch	Fuel/feedstock switch	
Cement		
Fugitive	Fugitive emissions	
HFCs		
N2O		
PFCs and SF6		
CO2 usage		
Landfill gas	LFG/methane capture and utilization	
Coal bed/mine methane		
Methane avoidance	Methane avoidance	
Afforestation	Nature-based solutions	Nature-based solutions
Reforestation		
Agriculture*		
* … Agriculture was split case-by-case, see paragraph before table		

Variable overview

The following table provides variable descriptions and availability for the complete sample of registered projects across registries, as featured in the final data before sub-sampling and cutting out observations pre-2009,

Table 5 - Variable overview

Name	Description	Availability		
		CDM	Verra	GS
identifier	Project ID within the registry (nu,)	Y	Y	Y
registry	Name of registry (i,e,, regulator) (ch,)	Y	Y	Y
project_title	Project title (ch,)	Y	Y	Y
proponent	Project proponent (ch,)	N	Y	Y
pa_poa	Indicator for single project or wider programme (ca,)	Y	N	Y
methodology	Project methodology (ch,)	Y	Y*	Y*
emi_red	Est, annual emissions reductions in mtCO2e (nu,)	Y	Y	Y
type_harmonized	Harmonized project type (UNEP DTU) (ca,)	Y	Y°	Y°
type_collapse	Collapsed harmonized project types (ca,)	Y	Y	Y
type_collapse2	Further collapsed harmonized project types (ca,)	Y	Y	Y
size_harmonized	Harmonized project size (CDM) (du,)	Y	Y°^	Y°
country_harmonized	Harmonized project host country (WB) (ca,)	Y	Y	Y**
region_harmonized	Harmonized project region (WB) (ca,)	Y	Y	Y**
income_harmonized	Harmonized income group (WB) (ca,)	Y	Y	Y**
reg_date	Project registration date (da,)	Y	Y	Y°
reg_year	Project registration year (nu,)	Y	Y	Y°

regyear_collapse	Project registration year, five-year bins (ca,)	Y	Y	Y°
vvb	Validation body at registration (ch,)	Y	Y^	N
VCM_dummy	Indicator for registration with VCM (du,)	Y	Y	Y
valstart_date	Validation start date (da,)	Y	N	N
vst_year	Validation start year (nu,)	Y	N	N
crediting_type	Type of crediting period (ca,)	Y	N	N
crediting_start_1	1st crediting period start date (da,)	Y	Y~	Y~
cst_year	1st crediting period start year (nu,)	Y	Y~	Y~
crediting_end_1	1st crediting period end date (da,)	Y	Y~	Y~
first_issuance	1st credit issuance date (da,)	Y	Y	Y
iss_year	1st credit issuance year (nu,)	Y	Y	Y
issued	Indicator for credit issuance (du,)	Y	Y	Y
installed_capa	Installed capacity (in MW) (nu,)	Y	N	N
IRR_bench	Internal-rate-of-return benchmark (nu,)	Y	N	N
IRR_exclcredit	Internal-rate-of-return without crediting (nu,)	Y	N	N
IRR_inclcredit	Internal-rate-of-return with crediting (nu,)	Y	N	N
afolu	List of AFOLU activity scopes (ch,)	N	Y	N
sdgs	List of certified SDG activities (ch,)	N	Y	Y
add_cert	Name of additional certification product (ca,)	N	Y	N
area_ha	NbS project area coverage in hectares (nu,)	N	Y^	N
trans_type	Type of project transition (ca,)	Y°	Y°	Y°
trans_id	Project transition identifier (nu,)	Y°	Y°	Y°

Legend
Y … Yes, i,e,, the variable is available for all observations
N … No, i,e,, the variable is not available for any observations
(nu,) … “numeric” variable, i,e,, discrete number
(ch,) … “character” variable, i,e,, uncategorized names
(ca,) … “category” variable, i,e,, categorized names
(du,) … “dummy” variable, i,e,, binary category
(da,) … “date” variable, i,e,, number in date format
° … variable had to be manually processed in some form
^ … variable had to be web-scraped
~ … not tracked reliably for a substantial amount of observations
* … variable not available for some projects (fully circumvented in harmonization)
** … variable not available for some projects (i,e,, classified as “international”, 6 obs,)

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