What is at Steak? Livestock-based Offset Schemes and the Transition to Net Zero

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Abstract

Climate and cow inventory data used to generate future emission scenarios at the regional level.
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Abstract
The emerging carbon economy presents opportunities for incentivizing farmers in the transition to low carbon systems. However, the design and implementation of voluntary carbon offset programs is faced with several challenges. Using the case of livestock-based offset schemes, this paper provides a critical analysis of the relevant considerations in the effective design of these programs. The first part of the paper discusses the issue of spatial heterogeneity in opportunities costs resulting from mitigation policies that limit cattle inventory. The paper reports forecasted estimates for seven regions (South America, Asia, Africa, Central America, North America and Oceania) under two carbon price scenarios. The paper then discusses various institutional issues i.e., quantification, verification and allocation of property rights to offsets in livestock systems. The paper concludes by discussing the possibilities for creating effective livestock-based carbon offset systems.

Keywords: livestock; net zero; carbon economy, cattle; emissions.
Introduction

Agriculture¹ makes an important contribution to global Greenhouse gas (GHG) emissions accounting for about 20% of all GHG emissions from anthropometric sources globally (Food and Agriculture Organization (FAO), 2019; Smith et al., 2014). This is unlikely to abate due to the projected growth in population and increased demand for meat, mostly in developing countries (Alexandratos and Bruinsma, 2012; OECD-FAO 2020; Robinson et al., 2015; Springmann, 2018; Grossi et al., 2019; Searchinger et al., 2019). At the same time, concerns about the harmful impacts of climate change are on the rise leading to a global effort by key stakeholders to reduce GHG emissions across all sectors (e.g., agriculture, energy, transportation etc.) (Schiermeier, 2019). These measures are consistent with commitments under international climate agreements such as the Paris Climate Agreement, and multi-country multi-sectorial goals of achieving net zero emissions by 2050 (WRAP, 2022; United Nations, 2023). For the livestock sector, the impetus to achieve net zero emissions is driven by the sector’s contribution to overall agricultural GHG emissions (FAO, 2017; Menegat et al., 2022; Amon et al., 2021). About 30% of global methane and 50% of nitrous oxide emissions from anthropogenic sources are emitted by the livestock sector (Saunois et al., 2020; FAO 2015; Key and Tallard, 2011).

Major multi-national agri-food corporations have launched their own carbon programs as part of a broader environment, social and governance (ESG) strategy. It is widely believed that the need to reduce emissions by these agri-food stakeholders is likely to extend beyond scope 1 and 2, to scope 3 emissions. The latter requires that firms track all upstream and downstream emissions (Kaplan and Ramanna, 2021). The tickle down effect of these new corporate initiatives is the increased stringency in farm-level emissions and potential structural impacts on livestock farms. Added to this is the changing public policy inertia towards the direct

¹ Including forestry, and other related land use
agriculture GHG regulation - see evidence in New Zealand, Ireland and Denmark (Henderson et al., 2020; Bozzola and Cerroni, 2022; Smith, 2022). Although significant scope exists for the reduction in livestock-based GHG emissions through a variety of measures, it is widely accepted that economic incentives - such as those offered by the emerging voluntary carbon offset market - can facilitate agricultural stakeholders’ transition to low carbon systems (Niles et al., 2019). The design and implementation of these schemes; however, faces several challenges. Using the case of livestock-based offset schemes, this paper evaluates features of existing programs likely to impact its role in incentivising the transition to net zero in the livestock sector. The paper highlights the issue of spatial heterogeneity in opportunity costs faced by livestock producers. Global livestock systems are highly heterogeneous, and this impacts GHG mitigation and the transition to low carbon systems (World Bank, 2021). The context examined in this study is mitigation policies that target structural changes in the cattle inventory. The analysis combines data on cattle inventory, prices and emissions from six regions - Africa, Asia, Europe, Oceania (New Zealand and Australia), North and South America. A secondary objective is the analysis of some of the institutional issues impacting the effectiveness of livestock-based voluntary carbon markets. The paper concludes with a discussion of the implications of these outcomes for the emerging carbon economy.

Carbon offsets: An overview

Carbon offset markets offer a mechanism for the trading of carbon credits. These credits are certified reductions\(^2\) in GHG emissions. The structure of the two types of carbon market – compulsory and voluntary – are similar. The distinguishing feature is that legally binding limits are set on emissions by a regulator (government) on compulsory sectors as part of a cap-and-trade system. These sectors are typically large final emitters (LFEs) such as the energy and industrial sectors. The institution of limits creates a market for the trading of allowances

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\(^2\) 1 carbon credit is equivalent to 1 tonne of CO\(_2\)
amongst firms (see for the example the European Union Emission Trading System3) (Clarke and Jack, 2022). Further, firms in regulated market can buy credits from voluntary markets (e.g., agriculture) to offset a proportion of their own emissions and meet mandatory standards. Carbon offsetting therefore refers to the process of funding activities that reduce GHG emissions in one sector to compensate for emissions in another sector. The goal is to achieve set environmental standards such as carbon neutrality.

Although voluntary carbon markets are not directly implemented by governments, state and quasi-state agencies can play an important regulatory role by establishing the measurement, reporting and verification (MRV) framework. For example, the UK government regulates the Woodland Carbon Code, an assurance standard for woodland creation in the UK (Forkes-Rees, 2023). Similar State and Provincial programs are currently in operation in other countries (for example, see Government of Alberta, 2023). There are also a range of independently established offsets crediting programs (e.g., Climate Action Reserve, Verified Carbon Standard, Gold Standard, and American Carbon Registry).

The appeal of the emerging carbon economy for farmers is the potential to create win-win outcomes. This is by incentivizing farmers to reduce their own emissions whilst earning revenue from the sale of credits. At present, the agricultural-based voluntary offset market remains nascent in most countries. As shown in Table 1, there are at least twelve public carbon offset programs with active agriculture and waste protocols. However, not all the existing schemes have operational livestock protocols. These offset programs have three main primary functions: the approval of protocols/projects; the assessment of projects; and, the creation of a registry for the management (issue, transfer, retire) of credits (Aguila, 2014). For example, Alberta’s project-based credit offset program: i.) Registers and undertakes third party review

3 https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en
of projects; ii.) Allocate offset credits; and iii.) manages a credit trading system under a
domestic trading scheme (Baranzini et al., 2017). Livestock projects under the offset scheme
include the nitrous oxide emissions, reducing GHG from feedlots and selection for low residual
feed intake markers in beef protocols (Government of Alberta, 2023).

The legitimacy of carbon offsets has been widely contested (Paterson, 2010). This relates to
the integrity of offsets as well as the associated measurement and verification procedures. For
example, questions have been raised about the true equivalency of (biotic) carbon from short-
lived sources in livestock such as methane with those from fossil sources (Carton et al., 2021).
Other concerns such as leakage, non-additionality, permanence, double counting, and time
preference issues have been raised (MacKerron et al., 2009). Consequently, carbon offset must
meet the so-called PAVER conditions – Permanence, Additional, Verifiable, Enforceable and
Real (Pierce and Strong, 2023). Additionality is perhaps the most contentious as it stipulates
that offsets must represent reductions that would not have taken place without the incentive
payments. Whilst this is consistent with international standards and prevents the inefficient
allocation of funds (MacDonald et al., 2021), it may reduce farmer incentives to participate in
offset schemes. For example, a farmer practicing cover-cropping as a routine farm practice
several years prior to an offset scheme may not be eligible for credits under the scheme. As
this is not meet the additionality condition. This in contrast to other farmers in the same location
who adopt the practice due to incentives from the scheme. Further, the availability of lower
cost offsets from the uncapped sector can create a low-cost bypass for carbon and dampen
LFEs’ incentive to reduce their own emissions. This notwithstanding, if designed properly,
carbon offsets markets can lead to reduction in GHGs and the development of co-benefits
(MacKerron et al., 2009). This is in addition to the possibility of spurring innovation through
new technological developments (Gillenwater et al., 2007). Consequently, offset schemes can
be appealing to policymakers interested in reducing overall emissions whilst avoiding the political costs associated with other incentive-based measures such as carbon taxes.

Table 1. Examples of carbon offset programs by public sector (government)

<table>
<thead>
<tr>
<th>Name Crediting Mechanism</th>
<th>Year of Implementation</th>
<th>Jurisdiction (country)</th>
<th>Sectors covered</th>
<th>Existing livestock producer/protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberta Emission Offset System</td>
<td>2007</td>
<td>Province of Alberta (Canada)</td>
<td><strong>agriculture, CCS/CCU, energy efficiency, forestry, fugitive emissions, industrial gases, manufacturing, renewable energy, waste.</strong></td>
<td>Yes</td>
</tr>
<tr>
<td>Australia Emission Reduction Fund</td>
<td>2012</td>
<td>Australia</td>
<td><strong>agriculture, energy efficiency, forestry, fugitive emissions, other land use, transport, waste.</strong></td>
<td>Yes</td>
</tr>
<tr>
<td>British Columbia Offset Program</td>
<td>2016</td>
<td>Province of British Columbia (Canada)</td>
<td>energy efficiency, forestry, fuel switch, waste.</td>
<td>Yes</td>
</tr>
<tr>
<td>California Compliance Offset Program</td>
<td>2012</td>
<td>United States</td>
<td><strong>agriculture, forestry, fugitive emissions, industrial gases.</strong></td>
<td>Yes</td>
</tr>
<tr>
<td>J-Credit Scheme</td>
<td>2013</td>
<td>Japan</td>
<td>forestry, energy efficiency, waste, renewable energy, industrial gases, agriculture, fuel switch, fugitive emissions, transport, manufacturing.</td>
<td>Yes</td>
</tr>
<tr>
<td>Quebec Offset Crediting Mechanism</td>
<td>2013</td>
<td>Canada</td>
<td>Industrial gases, waste.</td>
<td>No</td>
</tr>
<tr>
<td>RGGI CO2 Offset Mechanism</td>
<td>2005</td>
<td>States of Connecticut, Delaware, Maine, Maryland, New Jersey, New York, Vermont (US)</td>
<td><strong>waste</strong></td>
<td>Yes</td>
</tr>
<tr>
<td>Republic of Korea Offset Credit Mechanism</td>
<td>2015</td>
<td>Korea, Republic of</td>
<td>energy efficiency, industrial gases, manufacturing, renewable energy, transport, waste</td>
<td>No</td>
</tr>
<tr>
<td>Spain FES-CO2 Program</td>
<td>2011</td>
<td>Spain</td>
<td><strong>agriculture, industrial gases, energy efficiency, transport, waste, buildings, and fluorinated gases</strong></td>
<td>N/A</td>
</tr>
<tr>
<td>Switzerland CO2 Attestations Crediting Mechanism</td>
<td>2012</td>
<td>Switzerland</td>
<td>energy efficiency, forestry, fuel switch, fugitive emissions, industrial gases, transport, waste</td>
<td>Yes</td>
</tr>
<tr>
<td>Taiwan GHG Offset Management Program</td>
<td>2010</td>
<td>Taiwan China</td>
<td>energy efficiency, manufacturing, transport, fugitive emissions, waste</td>
<td>Yes</td>
</tr>
<tr>
<td>Thailand Voluntary Emission Reduction Program</td>
<td>2014</td>
<td>Thailand</td>
<td>energy efficiency, renewable energy, waste, transport, forestry, agriculture</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Data source: https://carbonpricingdashboard.worldbank.org/map data; agriculture and waste highlighted for emphasis, N/A means information not available.

Livestock producer participation in offset schemes

A livestock producer faces the choice of maintaining status quo production practices or switching to an alternative practice with lower carbon emissions in order to earn credits. These alternatives include practices that lead to improvements in enteric fermentation, manure storage
and treatment, and improved rangeland management (Powers et al., 2009). Conditional on the institutional and regulatory environment, this decision depends on the perceived benefits of the new practice and revenue from the offset scheme less the transition cost (Figure 1). The institutional and regulatory factors comprise several considerations including the existence of protocols and pre-financing payment arrangements to reduce the implementation cost of specific practices. Indeed, the existence of robust protocols on different practices is the baseline condition for measuring, reporting and verification of emission reductions. The absence of protocols precludes farmers from adopting specific practices irrespective of their impact.

The cost considerations include direct implementation costs, compliance costs and productivity losses from the transition to alternative production practices. For example, the installation of anaerobic digestors on dairy farm requires significant capital investments. This represents direct implementation costs. The cost of compliance entails measurement, reporting and verifications costs. Further, different farmers face different opportunity costs pertaining to potential losses in productivity from the transition to alternative practices.

From Figure 1, benefit considerations include: potential direct economic benefits from the new climate friendly practice, revenue from the carbon market, and the value of co-benefits. Practices such as breeding for more feed efficient cattle or the use of feed additives may yield direct economic benefits in the form of reductions in feeding cost from improved feed utilization. Other practices may yield zero to minimal direct economic benefits. The installation of digesters can produce co-benefits such as cleaner energy and water quality improvements. In general, co-benefits refer to additional benefits generated alongside carbon reduction. This comprises benefits such as biodiversity conservation, soil health, water quality, ecosystem services, community/sustainable development benefits and climate resilience (de Vito Piscicello, 2023; McDonald et al., 2021). The existence of markets for these co-benefits can be important sources of additional revenue for sellers of credits (Krifka, 2017) and buyers who
may gain additional non-pecuniary benefits from being perceived as contributing to socially desirable goals.

Figure 1: Summary of key considerations for farm participation in livestock offsets schemes
Available evidence indicates that these additional economic benefits are the primary drivers for the decision to participate in offset schemes by certain segments of farmers. Pierce and Strong (2023) reported that the decision by farmers to install anaerobic digesters (AD) was primarily driven by the odour control benefits of AD installation.

2A Carbon price for different public offset schemes (2021) Data source: .worldbank.org/map_data

2B Carbon price for selected private offset schemes (2021)

Figure 2: Summary of carbon prices in existing private and public offset schemes
Further, farmers can receive additional revenue from the sale of credits. This is dependent on the price of carbon and amount of offsets generated. The carbon offset price under different offset schemes vary widely across countries and within the same country. Figure 2A shows the range of carbon price reported for existing public schemes in different countries. The value ranges from $152.58 in Switzerland to $6.82 in South Korea. Figure 2B shows the range of carbon prices for selected private offset schemes in the US (see Figure 2B). The implication of these differences in carbon valuation is the spatial and regional differences in producer incentives and net benefits from participating in offset schemes.

Carbon pricing and heterogeneity in incentives – An illustrative example

This section further explores the geographical differences in opportunity costs using global cattle inventory, cattle, and carbon price data. This illustrative example focusses on policies that impose limits on cattle inventory to achieve climate goals. Indeed, a key proposal to limit livestock GHG emissions is the reduction in cattle inventory (Eisen and Brown, 2022; Symons and Blade, 2022; Skokstad, 2019; Histov, 2013; EIP-AGRI Focus Group, 2017). This can be a consequence of a number of direct and indirect policy measures. The former includes policies that directly limit cattle inventory or provides incentives to farmers to cull cattle to meet environmental regulations or set aside pastureland for other land uses by limiting herd size (Levitt, 2021; Zanon 2020; Skokstad, 2019). The latter can result from the implementation of consumption-based policies that increases the demand for alternative protein sources and indirectly reducing cattle production (Lusk et al., 2022). The analysis is initiated with the examination of global trends in cattle inventory by region. Forecasts are based on autoregressive time-series model estimates for seven different regions. The lag orders were determined using the Akaike Information Criteria (AIC).
Figure 3: Cattle inventory forecast by region (2022-2050) [forecasted trends based on authors own estimation]
Figure 3 highlights the trends in regional cattle inventory from 1960 – 2020. Based on these trends, future trends are forecasted for the period 2021 – 2050. Historically, most of the world’s cattle inventory is in South America (SA), Asia (AS) and Africa (AF). These regions are projected to be the key growth regions from 2021-2050. Cattle inventory is expected to continue its downward trend in Europe (EU). In contrast, inventory will increase/stabilize in Central America (CA), North America (NA) and Oceania (AU_NZ). The implications of these trends are that the GHG emissions and the opportunity cost of carbon are likely to differ regionally under policy scenarios that target cattle inventory. Consistent with projected trends in inventory, Asia, Africa and South America will account for the bulk of GHG emissions from cattle. Cumulative overall GHG emissions from these regions will increase from 65% (2021) and 68% (2030) reaching 74% by 2050. A significant proportion of the growth is due to changes in emissions from Africa – 16.37% in 2021 to 27.04% in 2050. Europe’s contribution to overall GHG emissions from cattle is projected to markedly decline from 20.23% in 2021 to 12.41% by 2050.

Figure 5 shows the differences in pathways towards achieving a 30% reduction in GHG emissions (relative to the 1990 baseline). These reductions are consistent with a policy that targets structural changes in cattle inventory. It is evident based on the projected emission levels\(^4\) (2020-2050) that the incidence of the reductions will be highest in the developing regions of the world (Africa, Asia, Central and South America) as compared to other regions (Europe, North America, Australia (AU) and New Zealand (NZ)). The spatial differences in carbon reduction pathways highlights the differences in opportunity costs of limiting cattle inventory under different carbon price scenarios.

\(^4\) Emissions are based on the IPCC tier 1 i.e., simplified default emission factors.
Figure 4: This figure shows the forecasted contribution to overall GHG from cattle by region 2021 -2050
Figure 5: This figure shows the differences by region of the path towards achieving 30% reduction in emissions by 2050 relative to 1990 levels.
The opportunity cost is the forgone value of cattle from herd reductions. Figure 6 shows net losses estimated as the loss value of cattle less revenue from carbon credits at two levels carbon pricing. These losses occur in all regions with the exception of Europe. Consistent with the projected increases in inventory and emissions, Africa, South America and Asia face the highest opportunity costs.

Figure 6: This figure shows the difference in the average value of inventory loss and revenue from carbon offsets (2020-2050) at high (100USD/ton) and low (50 USD/ton) carbon prices. Note: global cattle prices obtained for the Kansas cattle website.

Structurally changing the cattle inventory to limit the environmental impact can be considered a higher cost pathway as compared to other measures such as the use of feed additives, manure storage practices, adaptive multi-paddock grazing and breeding (Stanley et al., 2018; Searchinger et al., 2019; Jia et al., 2019). However, it highlights the potential macro-level spatial heterogeneity in incentives faced by livestock producers in the transition to low carbon systems. Boaitey et al., (2019) reported similar spatial variations in opportunity costs with respect to breeding for more feed efficient cattle and participation in offset schemes amongst

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5 The uniform price of cattle used in the present analysis may not reflect the full economic value of the livestock industry such as its contribution to rural economies and align industries (Eisen and Brown, 2022).
cow-calf producers in Alberta. The implication of these micro-level differences in opportunity costs and producer incentives are likely to persist at the macro-level. Carbon pricing in livestock schemes must be adjusted to reflect the spatial differences in the opportunity cost of emissions. Such adjustments may however be challenging as the voluntary livestock offset market is largely nascent in most countries.

**Institutional considerations**

Three critical considerations underlay the creation of a robust institutional framework for carbon offsets in livestock systems. These are: the creation of a credible and widely accepted mechanism for the development of protocols and quantification of carbon reductions; a credible verification system that validates the purported reductions; and a robust value assignment mechanism (Gillenwater et al., 2007).

Most voluntary carbon offset programs are initiated by projects and protocols that lead to reductions in carbon. This necessitates the establishment of cause-and-effect relationships between specific practices and GHG emissions. These impact assessment activities are often a product of multi-year trials and the leveraging of existing scientific knowledge. Agricultural universities translate information from peer-reviewed research, International Panel on Climate Change (IPCC) methodologies and lifecycle accounting methods into usable farm accounting metrics/protocols. The multi-segmented nature of livestock supply chains means that the data to validate these outcomes are sourced from different stakeholders along the supply chain. For example, protocols on the genetic selection of low carbon cows (see Government of Alberta, 2023) involves synergistic relationships and data sharing between farmers, breed associations, breeding companies, agricultural universities etc. Three issues are relevant from the foregoing. First, given the choice of different emission reduction protocols, farmers are likely to opt for projects that are relatively easy to implement and not necessarily high impact with respect to emission reduction. For example, most of existing agricultural schemes in the crops and soil...
sector involves carbon sequestration and soil carbon measurement schemes that are relatively easy to implement due to the advancements in soil testing technologies. Secondly, sectors that have robust pre-existing co-governance mechanisms are more likely to develop multi-stakeholder programs based on these existing relationships. For example, The Nutrien carbon program links upstream and downstream (American Corteva Agriscience, Ingredion, Maple Leaf Foods, PepsiCo and Syngenta) well as third-party verifiers (Climate Action Reserve, Verra and Gold Standard) (Business Wire, 2021). In livestock, the dairy sector has a longstanding history of cross-stakeholder collaborations between farmers, milk recording organizations, breeders, dairy record processing centres etc. (Peñagaricano, 2020). These relationships may be crucial in facilitating the transition to net zero along the livestock supply chain. Further, these multi-stakeholder collaborations (Allen et al., 2020) can streamline carbon auditing and data sharing across multiple segments as individual farmers may not have the infrastructure and expertise to develop their own carbon accounting tools. In fact, the proliferation of carbon accounting tools is a major impediment to industry-wide credibility and the standardization of carbon accounting across different livestock supply chains. Leinonen et al., (2019) found 64 farm carbon accounting tools differing in scope, robustness, practicality, and ownership. An alternative to independent carbon assessment is retailer/processor-owned carbon accounting tools that mandates all supplying farmers to use a specific tool to measure on-farm emissions. This can enhance the credibility of emission estimates within a particular supply chain but limit farmers ability to supply to other processors with different carbon accounting tools. This is especially true if the measurement tool requires significant changes in farm practices. Arla- Foods, a major multi-national dairy cooperative, mandates that dairy farmers enrolled in their carbon program use the firm’s specialized Climate Check tool. Farmers receive 3 eurocent/kilo for sustainability activities and 1 eurocent/kg for submitting Climate Check data (Arla Foods, 2022). Cargill, a major beef processor has launched a
sustainable certification program for beef farmers in Canada (Cargill, 2022). These measures are also occurring further down the value chain i.e., in the retail sector. For example, the Low Carbon Beef (LCB) certification has recently been approved by the USDA. The LCB certification requires that farmer using the label reduced their GHG emissions by at least 10% below a specified baseline (Reynolds et al., 2021; Low Carbon Ranch nd). Given the degree of market consolidation in livestock value chains (Karali et al., 2019), the concern is that farmers may lose access to specific markets if they do not participate in particular programs. Further, the opportunity to earn premiums in the retail market for low carbon meat raises the question of whether the same carbon reductions could be sold on the offset market. This would amount to double counting.

Carbon offsets are considered economic intangibles (Gillenwater et al., 2007) as both sellers (farmers) and buyers cannot observe the perceived reductions. This poses a number of challenges. Buyers cannot directly observe the actions and cannot ascertain whether the reductions in carbon emissions have actually taken place. Additionally, farmers have private information on the opportunity cost of different practices and are more likely to opt for practices with lower opportunity costs. This information asymmetry impacts sellers’ ability to ascertain whether farmers would have undertaken specific practices without payments from offsets. This has implications for the additionality condition (Mason and Patinga, 2013).

Measures such as two-part contracts have been proposed to induce incentive compatible behaviour (Mason and Patinga, 2013). Whilst third-party auditing enhances the environmental integrity of offsets - conditions of additionality, permanence and credible baseline approach should be met (Schneider and La Hoz Theuer, 2019; Aldy et al., 2010). Left unchecked, sellers have an incentive to select a business as usual (BAU) scenario that leads to over-crediting (Pierce and Strong, 2023; Badgley et al., 2022). For livestock, the degree of reduction in carbon
emissions depends on a range of factors including climatic factors, soil type, the weight and age of livestock etc.) (Foucherot and Bellasin, 2011).

There are several stakeholders (traders and brokers, exchanges, project developers, retailers and wholesalers) in the carbon product cycle who perform a variety of functions. The challenge for individual farmers is that they often lack the necessary scale and the technical knowhow to assess, verify and sell offsets. The transaction and compliance costs associated with auditing and reporting requirements can be a significant impediment for some farmers. The cost of implementation of specific projects also impacts farmer participation. Intermediaries such as brokers and aggregators offer varied solutions pertaining to reducing the transaction costs of participating in offset schemes. Aggregators aggregate offset from a number of farmers to reduce the transaction cost per farmer. Other intermediaries provide technical and financial services in exchange for a proportion of carbon offset revenues (Subler, 2006). For example, some brokers leverage their technical expertise and develop private-public funding models to finance carbon offset projects. The question of who gets what and how much becomes one of principal importance given the role of offset revenue in incentivizing farmer participation in offset programs.

The carbon cycle is intrinsically linked with the food production cycle. This means that the issue of the changing cattle ownership along the supply chain is likely to have implications for the distribution of carbon credits. For example, cattle production in most countries occur in segmented production systems where breeding, production, finishing, and processing are separate standalone operations. Questions remain on how carbon credits are distributed along this supply chain if credits are allocated further down the chain. Further, considering that the practice of farming on rented land is not uncommon in many countries, the issue of default ownership of carbon credits generated on (grazing) land is also relevant. For example, default rights to carbon offsets under the Alberta conservation protocol is retained by landowners and
Carbon contracts can be used as a mechanism to address the challenges associated with stakeholder coordination and the assignment of property rights in livestock supply chains. Several aspects of contracts – parties and terms, management obligations, data privacy, termination, impacts stakeholders’ benefits – are critical to the effectiveness of schemes. The terms of carbon contracts typically range from 10-15 years although terms of 125 years have been reported\(^6\) (Ware, 2022). This raises additional issues of land tenure and temporal variation in the quality of carbon credits considering the variability in the climate and ecological factors that impact farming and their potential impact on carbon reductions.

It is obvious from the foregoing that the development of voluntary offset programs faces significant governance and regulatory challenges with direct implications for carbon quality and integrity. The lack of stakeholder confidence in the quality of offsets impact the sustainability of these programs, and the resulting environmental benefits. This can expose buyers of these offsets to reputational and legal risks. To address the void in governance, it has been suggested that stakeholders rely on externally sourced offsets that are managed under well-established crediting systems such as the Gold standard (Foucherot and Bellasin, 2011).

The limitation of such an approach is that it can inhibit the development of localized protocols with sufficient flexibility to cater to the environmental needs within specific jurisdictions. Alternatively, public policies at the national level can regularize these voluntary schemes and improve carbon integrity. Public agencies in the US such as the Securities Exchange Commission (SEC), The Environmental Protection Agency (EPA) and the US Department of Agriculture (USDA) have ongoing initiatives aimed at enhancing additionality, standardization and reporting in US voluntary markets (SEC, 2022; EPA, 2023). Similar efforts have been

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\(^6\) Land-based protocols under the California Air Resources Board have a 25-year payment period and a 100-year monitoring period during which there is no payment (https://extension.psu.edu/what-should-i-think-about-before-signing-a-forest-carbon-contract)
reported in Canada, Australia, and the UK (see for example, Government of Canada, 2021; UK Parliament 2007). Ultimately, a rigorous public policy environment can address the lack of government oversight and provide the favourable baseline conditions for the development of the nascent voluntary offset market. Individual livestock producer participation in voluntary market depends on the assessment of private benefits relative to the cost of participation. Improving the integrity of carbon credits enhances the value of carbon sold under these schemes and the private benefits obtained by farmers.

**Conclusions**

There has been a rapid proliferation of voluntary carbon schemes in many countries although farmer participation remains low (Niles et al., 2019). These schemes are characterized by wide variations in scope, structure, and pricing (World Bank, 2022). This lack of harmonization impacts their effectiveness within and outside different jurisdictions. If the opportunities offered by the emerging carbon economy are to achieve the desired impacts, the necessary design and regulatory bottlenecks must be addressed. This article examined some of the regulatory and program design issues related to carbon offset schemes in livestock systems. The livestock sector is relevant, given the sector’s contribution to overall agricultural GHG emissions and the peculiar challenges faced by producers in implementing climate mitigation practices. As shown in the present analysis, the challenges posed by the regional differences in opportunity costs, pricing and lack of regulatory oversight must be addressed. Livestock producers in regions with high projected growth in inventory and emissions are likely to face significant net economic losses from mitigation policies that target structural changes in the cattle inventory. Carbon credits based on uniformly pricing emissions are unlikely to offsets the losses in the forgone value of cattle. Comprehensive pricing schemes that account for the value of other co-benefits such as the contribution of grazing cattle to biodiversity and conservation (Wirsemus et al., 2011) can provide additional incentives. Providing avenues for farmers to negotiate carbon prices amongst multiple buyers or the creation of pricing schemes
that reflect the opportunity cost of carbon across different regions can increase farmer participation in these schemes. Instituting the necessary governance and regulatory mechanisms can address the current regulatory gaps in most countries. This is an opportunity for government and the other relevant public agencies to meet local and international climate obligations by harmonizing the measurement, verification, reporting and credit allocation systems within voluntary markets. A robust and transparent voluntary carbon offset system can create win-win outcomes for livestock farmers and other agri-food stakeholders.

Declaration of interest: None
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