Carbon-Based Public Financing: Configuration of local NPPs and emissions, and corresponding financial modulation

Gaurav Biraris
gauravbiraris@live.com

Abstract

This paper facilitates a generic framework for carbon based public financing, which can be used by governments. Any government can make efficient journey towards the carbon neutrality goal by integrating this framework with fiscal policy & budgeting. MOD17A2HGF v061 dataset provides net photosynthesis (PsnNet_500m) value for each 500m pixel on earth. Our idea is to compute net CO_2 fixation in each sub-territory. On other hand, net CO_2 emissions can be estimated in the sub-territories through traditional methods. Local carbon index (LCI) for each sub-territory w.r.t. territory of the government can be calculated from the fixation & emission in each sub-territory. LCI can be coupled with fiscal incentives or dis-incentives.

1 Introduction

Public financing mechanisms traditionally operate through standardized frameworks embarking on economic, demographic, social and political considerations, with limited integration of environmental metrics. Such disconnection between fiscal policy and ecological impact represents a significant gap in governance structures worldwide as climate change intensifies and carbon management becomes increasingly critical. Current budget design processes typically incorporate environmental concerns as secondary considerations rather than foundational elements, resulting in fiscal policies that may inadvertently counteract climate mitigation efforts.

Current environmental measures in public financing remain fragmented and often peripheral to core budget structures. The typical instruments available for governments include carbon taxation [1], emissions trading schemes [2], debt-for-climate swaps [3], green bonds [4], carbon offsetting [5], subsidies etc. But all of these operate largely disconnected from mainstream fiscal policies. They intrinsically need listing or identification of the concerned activities by the authorities, and subsequent proactive monitoring that's often skipped. Some of the financial tools typically function as reporting mechanisms rather than decision frameworks. Many jurisdictions struggle with conflicting incentives where environmental subsidies operate alongside continued support for carbon-intensive industries. There is no generic environmental instrument for systemic fiscal policy.

The limitations of current approaches include inadequate domestic differentiation of environmental policies, with most measures applied uniformly across jurisdictions despite significant ecological variation. In fact, by characterizing the internal sections based on net

carbon footprints, they can be maneuvered towards climatic sustainability. Additionally, environmental metrics rarely influence formula-based fiscal transfers to subnational/substate governments, representing a missed opportunity to align intergovernmental finance with sustainability objectives. This creates a structural inefficiency wherein government expenditures, taxation policies, and grant allocations may operate in environmental isolation, potentially undermining broader sustainability goals.

There is no cornerstone in fiscal planning that would facilitate synchronous use of all the instruments available for climatic welfare.

This paper introduces a methodological framework to enable carbon-based public financing. By developing spatially explicit carbon indices for each sub-territory/subsidiary, this approach allows governments to calibrate fiscal instruments according to localized environmental conditions and carbon profiles. The methodology provides quantitative grounds for differentiating financial incentives and disincentives across territories based on their carbon fixation and emission characteristics, effectively embedding climate considerations into core budgetary processes. The statistical indices can be coupled with other climatic instruments to accelerate the journey towards net-zero goal.

We present a public financing model that can be adopted by governments.

2 Road to Sustainability

Objective is to offer an effective public financing model that can be used by governments irrespective of their hierarchical level. Plenty of governments including national, state and local governments have genuine commitments to achieve climatic sustainability or net-zero goals. Here we present public financing model that can be used by such governments.

Offsetting of CO_2 emissions at micro levels would be biggest step towards the sustainability. Key to success towards any public goal is to couple it with financial constraints. Financial benefits encourage the aligned human conduct.

We expect effective environmental practices by coupling the anticipated practices with public finance.

Crux of the idea is to configure annual emissions and sequestrations within the territorial boundaries. Then to assign an index of carbon imbalance to each sub-territory (ward/block/district/province depending on hierarchy of the adopter government), and use this index for public financing. For financial relief, people (and sub-governments) should try to reduce the index by reducing carbon imbalance.

Additionally, kg scaled local carbon credits (LCCs) can catalyze the impact. In case of the adverse index, the government can enforce buying of the LCCs for various governmental processes. As

LCCs are generated by carbon fixation, transactions of LCCs imply the steps towards net-zero goal. The schemes of LCCs and the local indexing can work synergistically.

Coincidentally, we have the essential dataset openly available to facilitate the index calculation at enough resolution.

3 Methodology

We have MODIS dataset [6] about gross primary productivity and net photosynthesis openly available with pixel size of 0.25 km^2 for entire earth. Each pixel denotes certain amount of CO_2 sequestered in the 500mx500m area in units of kgC/m^2/8day. This satellite originated dataset is updated routinely, and we can get most recent dataset of each day.

Suppose, a government wants to adopt the framework. Then, it has to analyze the MODIS data pixels in each sub-territory. It should yield carbon fixation data in the sub-territorial boundaries. Dividing the fixation density of a sub-territory by the overall fixation density, we get relative fixation density. Relative fixation suggest, which parts are fixing more CO_2 and which less wuth reference to whole governmental territory. Discrepancies and errors can be reduced as discussed in next section.

On other hand, emissions in each sub-territory can be configured from commerce data (e.g. total sales/consumption of fuels, electricity, biomass etc.). Similar to the fixation, we can get relative emission density for each sub-territory by simple statistics.

If we subtract relative fixation from relative emission, we get measure of carbon imbalance w.r.t. the parent territory. Use of the relative quantities rather than absolute ones facilitates better statistical appreciation of both emission and fixation in the sub-territory w.r.t. overall geography.

As explained in next section, we get an index that implies surplus relative emission of each sub-territory adjusted over pixeled area. Let's call this index be Local Carbon Index (LCI). Such LCIs of sub-territories can be used in various ways by the governments. The sub-territories of higher LCI can be incentivized while those of lower LCIs levied.

Apart from scheme of LCI, the framework has distinct feature of Local Carbon Credit (LCC). Carbon credits are adopted worldwide, but their scale is large, corresponding to fixation of 1 ton CO_2. Issuance and accounting of the carbon credits is of global scale. In order to appreciate local or small scaled green activities, kg scaled carbon credits can be recognized. Local government itself can issue or recognize the kg scale LCCs in the territory. Household plantation, landscape greenery, gardens, open plantation etc. qualify for accounting of kg scaled carbon fixation annually. CO_2 fixation is directly calculated from dry weight of the plant, and dry weight is direct correlated with weight or growth rate of the plant. Hence issuance and accounting of LCCs by the local governments (or recognized third parties) is straightforward.

If demand of LCCs is encouraged, then people/organizations would go for LCC generation which in turn causes plantation and CO_2 fixation. Governments can seed demand for LCCs in various ways.

4 Use Cases for Governments

By revising LCIs at constant interval, say annually, governments can maneuver citizens for climatic activities. The framework can be used in other ways by the governments. LCIs give idea about relative carbon imbalance. It gives freedom to use it in any context. Scale/extent to which LCIs should impact normal circumstances is to be decided by the local governments/policymakers. Some bodies may choose harsh coupling, some may go for loose. As LCI computation is generic, global compliance is possible. Trade of LCCs would encourage compliance among different boundaries.

The governments vary in terms of capacities and functions depending on hierarchy. Hence different governments can adopt the framework depending on respective capacities. It has multiple use cases for each government ranging from local to national. We can elaborate the use cases depending on capacities of the government as follow.

4.1 If disburse funds

If a government disburses funds to sub-entities, then LCI can be considered as a factor along with other factors while decision making. If better LCI encourages more funds, then the sub-entities should try to improve their LCIs by approach towards net zero. Extra funds can be disbursed to the entity having excellent LCI.

LCI tailored fund disbursement is the prime tool of the carbon based trade financing for higher governments of states and nations. If such governments pursue LCI tailored fund disbursement to it's sub-entities for a decade, we shall see tangible effects on ground. Politicians often seek higher government funds. If improving the LCI is the way to harvest more funds, then over the period all politicians would go for green activities or reduction of emissions, without quarrel.

4.2 For central governments

The framework has special significance for central (i.e. national or state) governments. LCIs and LCCs can be used in numerous ways for policymaking. As the taxation by central governments is more organized, it can be more effectively coupled for the net-zero goal.

Basically, central governments can identify economical activities those cause environmental impact, and classify them as red and green activities. Red activities are those which adversely affect environment such as GHG emission, biodiversity harm etc. On other hand, green activities are those which balance or mitigate adverse impact such as CO_2 fixation, renewable energy etc.

Stakeholders of red activities (i.e. manufacturers, traders and consumers) can be required to have certain LCCs. Stakeholders of green activities can be provided reliefs. Extent of the LCCs required or reliefs offered can be varied depending on LCI of the locality of the stakeholder. This model is compatible with conventional taxation machinery as accounting, monitoring and return filing of economic activities is well established.

Examples of green activities include plantation in backyards and frontyards, solar heater installation/service, solar PV install/service, EV purchase, home insulation, seeds, nursery, rooftop gardens, shared transport, bicycles etc. Examples of red activities include automobile, room heaters, water heaters, refrigerant, cooking fuels etc. LCCs can be coupled with the sales tax or GST for the red and green activities.

4.3 If enforce taxes

Some governments enforce taxes. Resident taxes like property tax, income tax, local body tax etc. can be varied based on LCIs. Boundary taxes like octroi can be put with LCCs; for instance, certain LCCs can be required for the transaction/entry above a threshold limit.

If the government enforces cess or duties, then LCI or LCC can be taken into account for variation instead of uniform rates.

Reliefs or rebates against the taxes can be offered in an individual/institute holds certain LCCs.

Corporate taxes can also be tailored based on LCIs. LCIs of the industrial colonies or factories can be considered while levying the corporate tax. In case of better LCI, tax relief can be given.

4.4 If offer paid services

Many local governments offer charged or paid services. Water charges is the typical example, some bodies provide electricity, LPG, garbage collection etc. also as charged services. These services are charged at uniform rate for all residents. The charges can be varied depending on LCIs of the localities. Basically, different charges for different sub-territories are straightforward. But it is possible to do the variation at the ward level as MODIS dataset has spatial resolution of 500m.

Apart from the utility services, other fees can also be varied based on LCI. Fees of parking spaces, parks, swimming tanks, playgrounds etc. can be decided by using LCI as a factor.

If transport services (bus, trains, metro etc.) are provided, then the fair rates of the routes can be varied based on LCI. LCI linked fairs should try to compensate excessive emissions in some localities.

Eventually, people shall appreciate that the charges or fees can be reduced if LCI of the locality improves. It boosts tendency towards plantation or emission reduction.

4.5 Apropos referencing

LCIs and LCCs can be concerned for any relevant decision. LCIs can be referred while deciding site of development works if decision is not possible with other factors. LCIs can also be referred while giving permissions to certain events. Fireworks and vehicle gatherings are involved in some events, which cause more CO_2 emissions. LCI of the locality can be considered while giving permissions or NOC.

In the council/house discussions, LCIs offer a distinct factor for the stances (by members) with reference to the locality. LCIs and LCCs in the territory would facilitate a separate horizon for political discussions. Most of the environmental concerns can be politically configured in terms of LCI. Enough resolution (500m) of these properties makes them relevant in most of the circumstances.

4.6 If issue documents

Various certificates, licenses, NOCs etc. are issued by the governments for various compliances. Fees of such documents can be used to incentivize net-zero goal. In addition to typical fees, the applicants can be required to pay some fraction in terms of LCCs. This will create demand for LCCs. People will go for generation of LCCs aiming governmental documentation. Some people can think LCCs as income, as LCCs can be sold to others.

Quantity of LCCs needed for a document issuance can be decided based on LCI of the applicant's locality.

Industries can be required to purchase more LCCs for governmental documentation. If scheme of LCCs isn't pursued, then the fees can be charged based on LCI of the applicant's locality. This shall encourage people to improve their LCIs i.e. to pursue the green activities.

5 Executive Protocol

Here we will explain the steps of data analysis and inference step by step so that anyone can reproduce the models for specific adoption. The solution is generic. It can be adopted by literally any government (central or local) in world.

5.1 Datasets

Two datasets are needed for the adoption by each government. One is of the net primary productivity of photosynthesis done in last year in each sub-territory. And other is of the emissions done in last year in each sub-territory. The first data is worldwide available at [6] with resolution of 500m. The second data can be configured by the governments in various ways. A straightforward way is to account for annual sales of the emissive goods like fuels. Further, we already know carbon footprint of most of the goods in market. If the goods are manufactured in the sub-territory, then such footprints can be accounted for emissions. Based on the economic

survey of each year, the governments can configure emissions in each sub-territory. Many governments have configured districtwise emission data, it can also be concerned.

So, the carbon fixation data is openly available while emission data has to be obtained or configured by the governments.

5.2 Shapefiles

For geographical analysis in GIS softwares, we need shapefiles of territories.

We need shapefiles of territory of the government, along with shapefiles for sub-territories. Shapefiles for most of the territories in world are available already [8].

Sub-territories can be selected in a shapefile, can be saved as a separate shapefile. Else, corresponding data can be extracted from attribute table.

5.3 GIS Analysis

MODIS dataset is to be used for CO2 fixation analysis. It can be effectively done on the open source GIS analytic tool: QGIS. Many GIS softwares are available in market, but QGIS [7] is free and open source.

The MODIS dataset comes in hdf format. One can see the subdatasets in hdf file by opening terminal and entering the command 'gdalinfo' followed by the file name. There are 3 subdatasets in MODIS dataset, we must use second one "PsnNet_500m" as it gives net photosynthesis. Name of this subdataset should be pasted in QGIS through "add raster layer". This will fetch MODIS dataset in QGIS.

One can add many layers (i.e. different shapefiles, datasets, basemaps etc.) in QGIS for visualization or analysis. We should use "Zonal Statistics" tool of QGIS to get the statistical values for territories in shapefile. We should get sum and count of the MODIS data pixels in each sub-territory. As each MODIS pixel has a value of carbon fixation per area, this sum suggest sum of per area fixation over the territory; and the count is number of pixels in the territory.

Zonal statistics yields key results for any geographical boundaries, if the shapefiles are proper. Results can be screened through attribute table. Zonal statistics data can be exported in tabular form.

5.4 LCI calculations

Tabular data exported from QGIS can be used in spreadsheet program like MS Excel, to perform further calculations.

MODIS pixel has value in $kgC/m^2/8day$. When QGIS zonal statistics sums it over N pixels, we have to divide it by N to get resultant (average) value in $kgC/m^2/8day$. Multiplying it by area of

the territory we get the fixation in kgC/8day. Here C can be converted to CO2 (multiplying by 44/12) and /8day to /year (multiplying by 365/8).

Summing over all sub-territories gives total fixation in the territory. By dividing this total fixation by total area, yields resultant fixation density. Likewise, the fixation densities for each sub-territory can be obtained. Relative fixation density is obtained by just division by the resultant fixation density.

Likewise, emission calculations can be performed. Dividing the emissions by area, we get emission density. By dividing emission density of a sub-territory by the emission density of the territory, relative emission density of the sub-territory obtained.

Local Carbon Index (LCI) is nothing but the subtraction of relative fixation density of a sub-territory from its relative emission density.

In principle, the densities can be calculated by dividing population of sub-territory instead of its area. But use of the area makes better sense.

5.5 LCI Significance

LCI implies imbalance of relative densities of fixation and emission over the territory. Positive LCI means the region is emitting more CO_2/m^2 than the fixation as compared to other regions. Higher LCI suggests need of CO_2 fixation with higher extent. Negative LCI implies the region has better fixation compared to other regions adjusted over the emissions. Zero LCI implies perfect balance of carbon status w.r.t. entire territory.

LCI value is directly proportional to carbon severity of the region. Places of higher LCI can be imposed with heavier constraints, while those of low/negative LCI with reliefs. Places of higher LCI can be enforced to have/buy higher LCCs.

5.6 LCC

Execution of LCC can be done by assigning the power to recognize LCCs to a body. This body should record, certify and account LCCs. People can have plantation in their premises, and reach to this body. This body should record plant attributes (including species, age, expected gross weight, typical growth rates in literature, expected growth in next year etc.). A LCC can be issued (with unique tracking number) if the plant has chances to grow in next year to fix >1kg CO2. Quantity of CO2 fixation is direct function of expected growth of the plant/s in next year. The LCC certificate issued by the body can be used by people for regulatory/financial purposes. Such LCCs can be submitted to government for compliances, or can be sold to the people/institutes seeking LCCs for compliances. The local government can also facilitate a portal for exchange/trading of LCCs.

Scheme is: a notified body should certify generation of LCC, LCC can be exchanged as per demand-supply, and the LCC should lapse/sink once submitted for the compliance. A LCC can

be exchange worldwide if there is valid recognition of the notified body. Hence, soon LCCs would emerge as global commodity. A government can impose restrictions on import/export of LCCs or de-notify foreign bodies those issue LCC, whenever needed. Blockchain based trustless systems can be designed to eliminate the centralized notified bodies for LCC issue, verification and accounting.

LCC coupled with LCIs would facilitate a model for carbon based economies.

6 Conclusion

LCI and LCC coupled policymaking shall cause impact by discouraging carbon adverse activities and encouraging green activities. Carbon based economy can exist by LCI coupled public financing. Government of any hierarchy can configure LCIs for its constituent sub-territories.

Depending on functionality, the government can use LCIs in various ways as stated in section 4. Same government can implement/adopt LCCs. Simultaneous application of LCI and LCC offers several models (with compliance for policymaking) towards the net-zero goal.

By systematically incorporating carbon metrics into public financing decisions, governments can align fiscal policy with environmental objectives, potentially accelerating progress toward climate commitments while maintaining economic functionality. This integration represents a structural advancement beyond current approaches where environmental and fiscal policies often operate in separate domains with limited coordination.

A generic model of coupling the financial components with the environmental components can be used in policymaking worldwide at various levels of governance. Proposed solution facilitates compliance with policymaking while synchronizing public finance and environment. It offers several remedies towards net-zero goal, one or many of which can be adopted by the governments. It offers compliance for governmental hierarchy. Parent or child government LCIs not conflict and not relevant. Hence any government can configure and use LCIs irrespective of the LCI use by its parent or child government.

Ideally, LCIs should be updated annually. Then, people & sub-governments can easily appreciate impact of LCIs on their financial receipts/burdens.

References:

[1] Köppl, A., and Schratzenstaller, M. (2023). Carbon taxation: A review of the empirical literature. Journal of Economic Surveys, 37, 1353–1388. https://doi.org/10.1111/joes.12531

[2] Paola Villoria-Sáez, Vivian W.Y. Tam, Mercedes del Río Merino, Carmen Viñas Arrebola, Xiangyu Wang, Effectiveness of greenhouse-gas Emission Trading Schemes implementation: a

review on legislations, Journal of Cleaner Production, Volume 127, 2016, Pages 49-58, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2016.03.148

[3] Picolotti, Romina; Zaelke, Durwood; Silverman-Roati, Korey; Ferris, Richard (2020). Debt-for-Climate Swaps (PDF) (Report). Institute for Governance and Sustainable Development.

[4] Umair Saeed Bhutta, Adeel Tariq, Muhammad Farrukh, Ali Raza, Muhammad Khalid Iqbal, Green bonds for sustainable development: Review of literature on development and impact of green bonds, Technological Forecasting and Social Change, Volume 175, 2022, 121378, ISSN 0040-1625, https://doi.org/10.1016/j.techfore.2021.121378

[5] Lovell, H. and Liverman, D. (2010) 'Understanding Carbon Offset Technologies', New Political Economy, 15(2), pp. 255–273. https://doi.org/10.1080/13563460903548699

[6] MODIS/Terra Gross Primary Productivity Gap-Filled 8-Day L4 Global 500m SIN Grid V061 | Earthdata Search https://search.earthdata.nasa.gov/search/granules?p=C2565791029-LPCLOUDandpg[0][v]=fandpg[0][gsk]=-start_dateandq=C2565791029-LPCLOUDandtl=1346446110.639!5!!

[7] Download · QGIS Web Site https://qgis.org

[8] Data — DIVA-GIS https://diva-gis.org/data.html