INSTITUTE FOR SUSTAINABLE RESOURCES

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Financing national scale energy projects in developing countries: An economy-wide evaluation of Ghana's Bui Dam

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Future DAMS

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Introduction

Large infrastructure requirements:

- Global decarbonisation targets require investments in clean power generation, building efficiency, electrification of the transport sector, and low carbon technologies in other sectors of the economy
- To reach 1.5^{o}C, the average annual investment in low-carbon energy technologies and energy efficiency would need to increase by a factor of six by 2050 compared to 2015 (Rogelj et al., 2018)
- Two-thirds of the world's infrastructure investment is expected to occur in the Global South (NCE, 2016)

Access to finance:

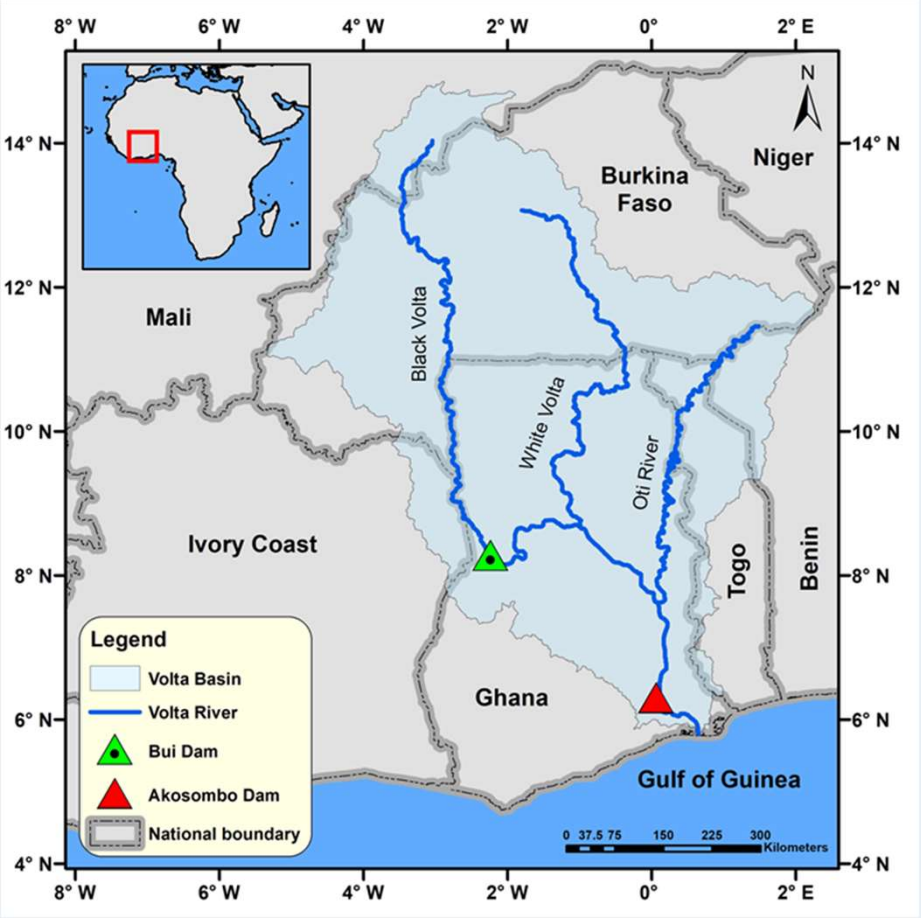
- Without external financing and by relying only on internal savings, the implementation of large-scale projects in developing countries may take a long time and can 'crowd-out' investment in other areas of the economy
- At the same time, foreign lending in developing countries with low credit rating are very often linked to specific conditions that can generate their own economic implications (resource-secured loans)

Research gap:

- Besides the importance of the capital investments and its financing conditions most of the work focus on assessing the operation of the asset. So, their emphasis is on assessing the direct impacts more than the indirect or induced effects (e.g. supply chain impacts, income effects).

The Bui dam

- The Bui Dam is located on the Volta River in Ghana.
- The Volta River Basin is in West Africa and is geographically shared between six countries
- The Volta River has three main tributaries: the Black Volta, the White Volta, and the Oti River.
- The construction of the Bui dam started in 2009 and hydropower generation was commissioned in 2013 with a power generation capacity of 400 MW.
- The Akosombo Dam, located downstream from the Bui Dam, is the largest hydropower plant in Ghana and the Volta Basin with a power generation capacity of 1020 MW.



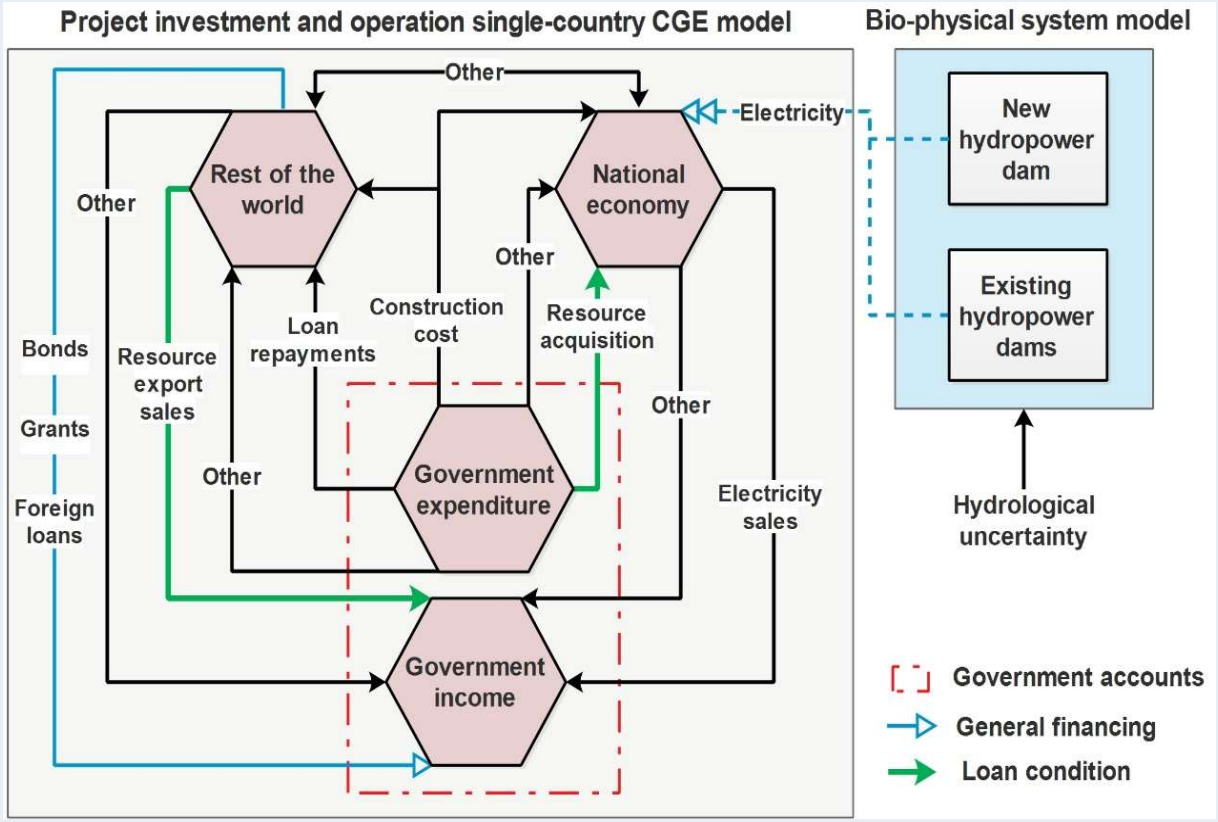
The Bui dam

Phase	Direct impacts
Construction	Project cost is 622 million USD. Construction duration: 4 years (2009-2012)
Financing	Total project finance is 622 million USD with the following breakdown: • 60 million USD from government spending • A 20-year concessional loan of 270 million USD at 2% interest • A 12-year commercial loan of 292 million USD at 1.03% over commercial interest reference rate (set at 3.5%); annual exports up to 40,000 tons of cocoa at the world price over 20 years (collateral of the loan agreement)
Operation	• Reduction in electricity generation from the Akosombo Dam during initial filling of the Bui Dam. • Added electricity generation from the Bui Dam. • Change in electricity generation from the Akosombo Dam during the steady-state operation of the Bui Dam as a result of river flow regulation by the Bui dam.

We **do not include** benefits of irrigation nor negative environmental and social impacts

Methodology

- A CGE model (InvestCGE) is linked to a spatially explicit, bio-physical system model.
- The economy model determines the macro-economic, sectoral and household level impacts of large-scale infrastructure (construction, financing and operation).
- The bio-physical system model determines hydropower generation considering hydrological uncertainty.
- The changes to hydropower supply are then transmitted to the CGE model as economic shocks to hydropower sector.



InvestCGE model

Single-country CGE model able to assess infrastructure projects across the construction, financing and operation phases of the project

- Based on the standard IFPRI CGE model (urban/rural households, skilled/unskilled labour, subsistence consumption, small-open economy)
- Calibrated to the Ghanaian economy 2009
- Recursive dynamic model (2009-2067)
- Endogenous labour supply (it increases with wages)
- Sector-specific hydropower capital
- Power generation is split into hydro and non-hydro
- **Construction:** It has a project construction activity (active only during the construction phase). So it reflects the real costs of the dam (imported turbines)
- **Financing:** Four financing options are implemented (bonds, foreign loans, foreign grants and government spending). It can include grace periods
- **Operation:** project-specific rents attributed to the project capital are separated from other rents. Operation and maintenance cost are deducted.

Bio-physical system model

Rule-based water simulation model simulates hydropower generation considering hydrological uncertainty

- Simplified monthly engineered system model developed for the Volta River
- Estimates electricity generation from the Bui Dam and the impact on electricity generation from the Akosombo Dam
- The model covers the period 1993-2013 and includes three inflow points to represent the three major tributaries of the Volta River
- The model was calibrated from 1993 to 2003 and was validated from 2004 to 2013
- The Akosombo reservoir was operated to target a constant power production while keeping the reservoir water level between the minimum operating level and the full supply level
- The Bui Dam was operated similarly during the steady-state phase
- During the initial filling stage, the Bui Dam was operated based on target reservoir storage values
- The hydrological uncertainty was generated considering 50 possible hydrological futures sampling from historical river flow records

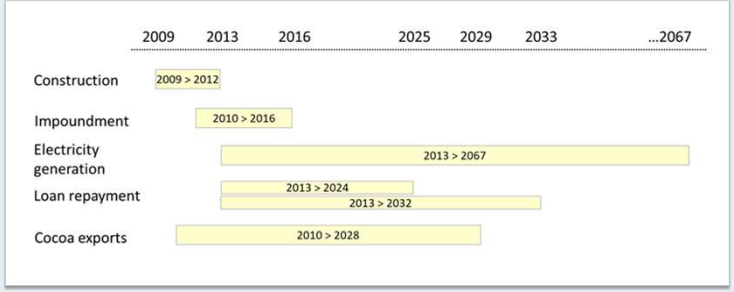
Scenarios (2009 – 2067)

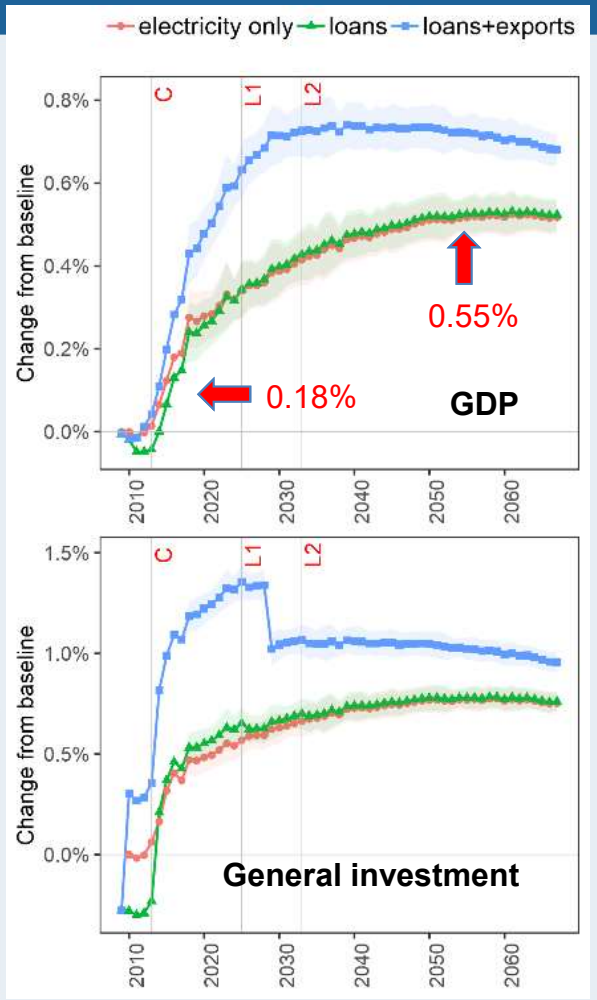
Bui Dam	Socio-economic development	Hydropower generation dynamics	Scenarios
Without Bui:	Population and labour supply changes based on SSP2 Endogenous capital accumulation	Historical hydrological conditions for 2009-2016 50 stochastic hydrological conditions for 2017-2067 (assuming historical variability, no climate change signal)	- **Baseline:** Electricity generation only from the Akosombo Dam
With Bui:			Electricity generation from the Akosombo and Bui Dam **- Electricity-only:** Increase in hydropower production without considering the investment and finance needs. Replicates previous impact assessments which consider only the operational stage **- Loans:** Includes in addition the construction phase of the dam and two government-backed loans (12-years and 20-years) **- Loans+export:** Includes in addition the cocoa exports over the 2010 - 2028 period (22,000 tons, 2.8% of the total production)

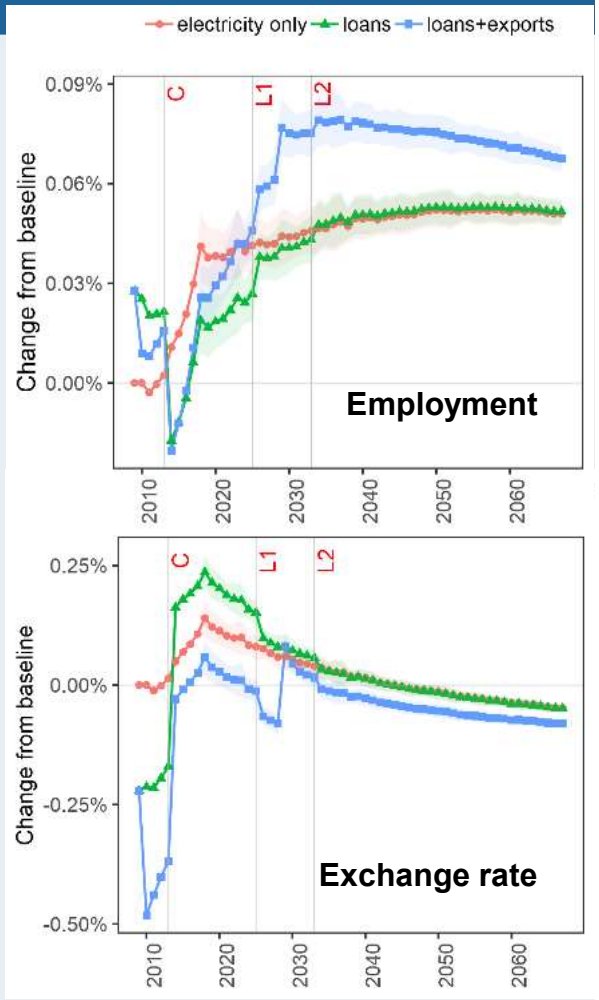
Macroeconomic impacts

Electricity only scenario: is expected to increase **GDP** by 0.18% (filling period) and by 0.55% (the long-term)

The increase in hydropower generation would lead to **positive effects** across the economy by increasing the output of non-energy sectors, exports of commodities, employment, household income and investment



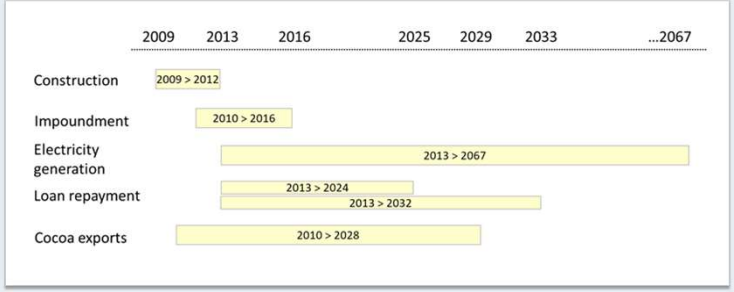


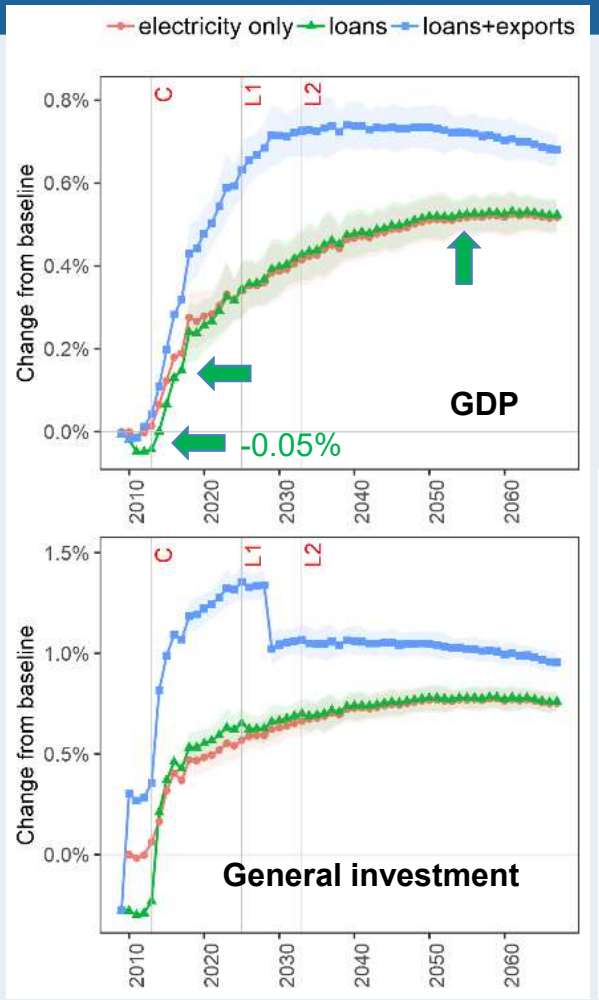


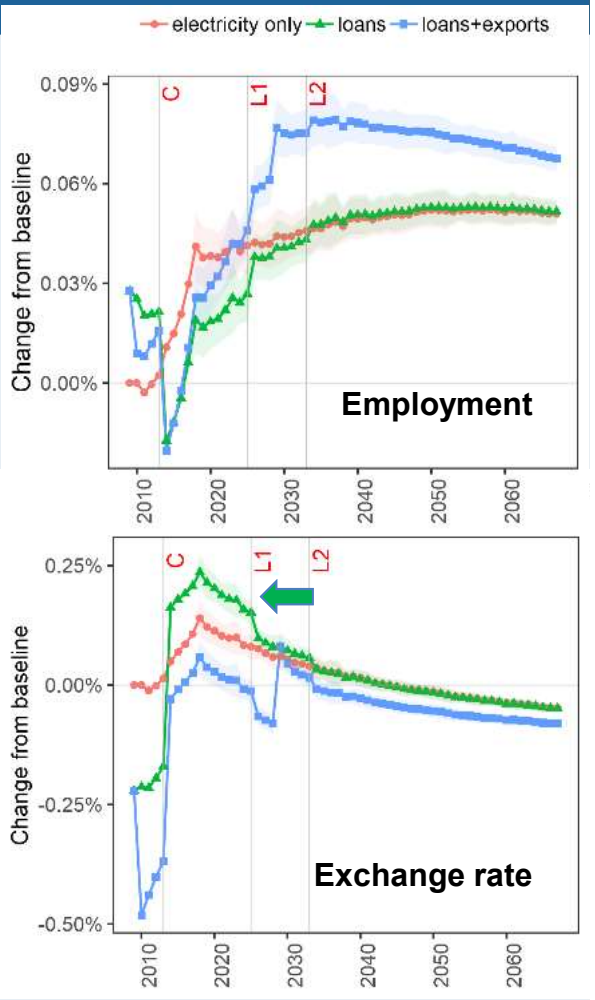
Macroeconomic impacts

Loans scenario: **GDP** declines (0.05%) during the construction phase: i) crowding-out effect in labour and capital, ii) higher investment cost outside the dam construction

During the operation phase, the repayment of the loans induce a **depreciation** of the domestic currency stimulating exports and economy growth



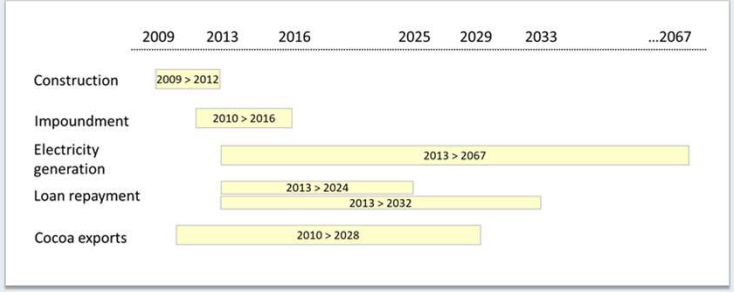


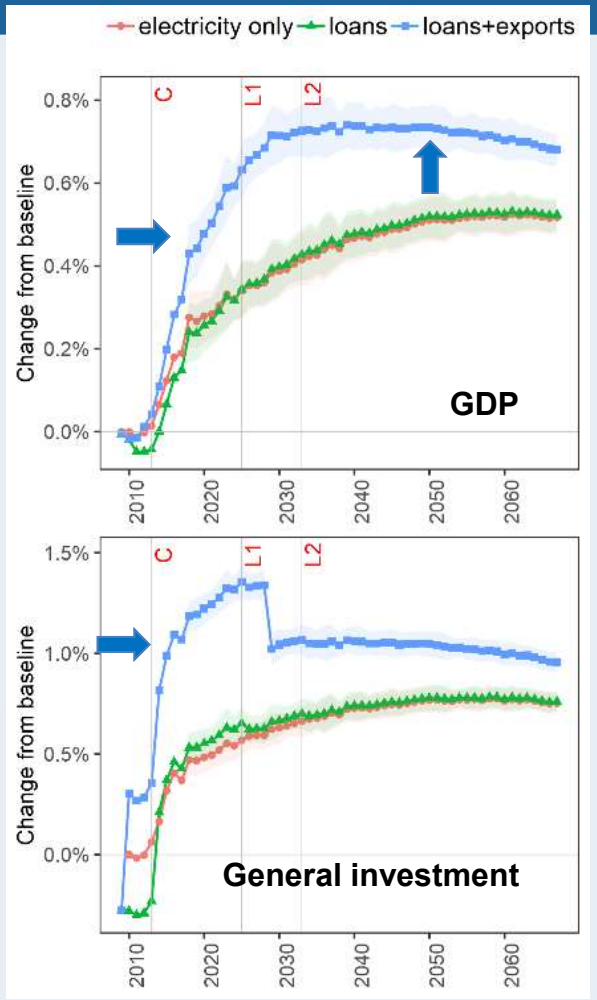


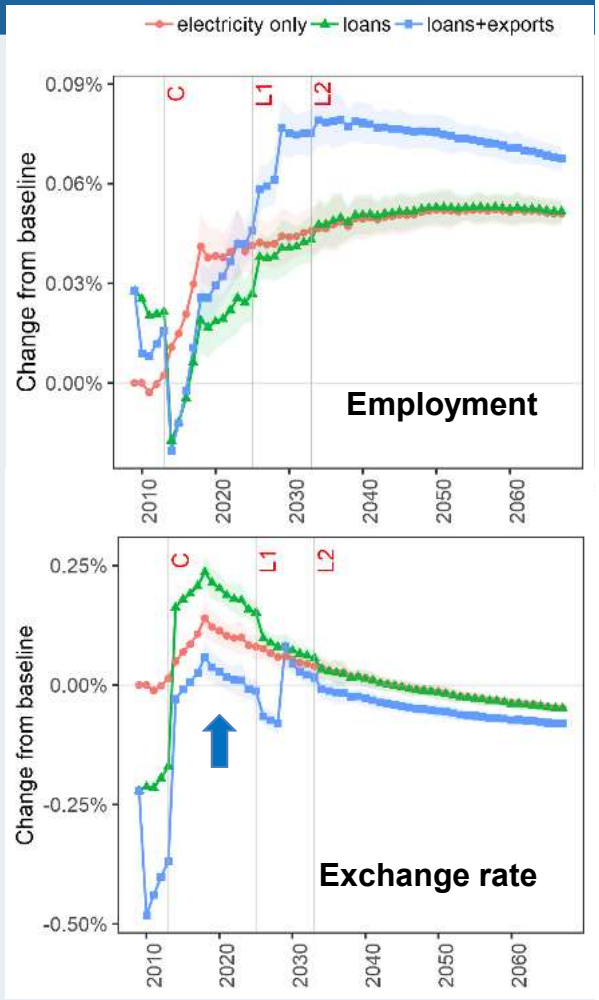
Macroeconomic impacts

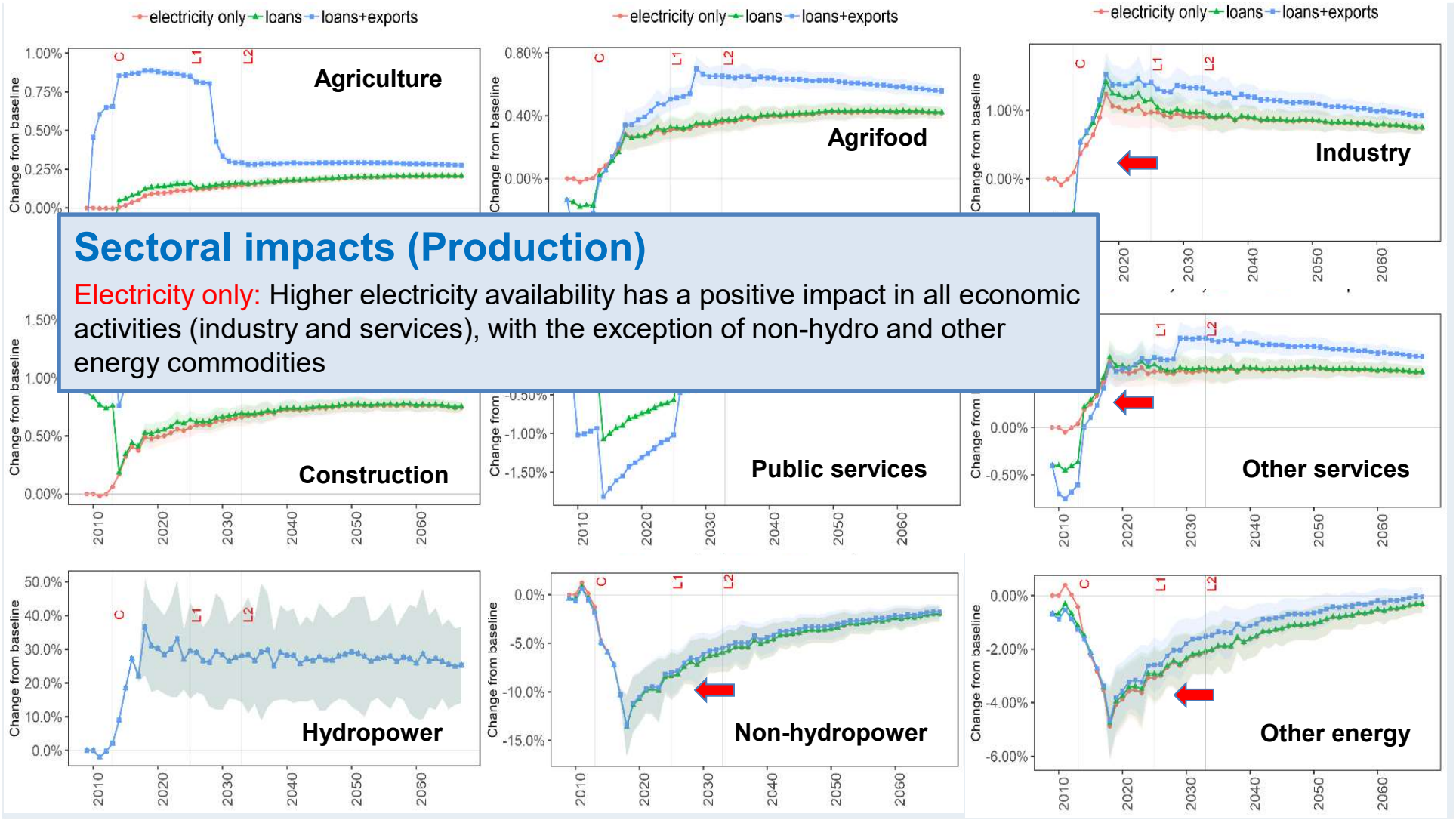
Loans+export scenario: **GDP** increase from 2010 to 2028 due to the cocoa exports agreement, this leads to a positive impact on investment (agriculture)

The increase in cocoa exports leads to an **appreciation** of the local currency, affecting negatively other exports. However the net effect for most economic sector is positive (long run)



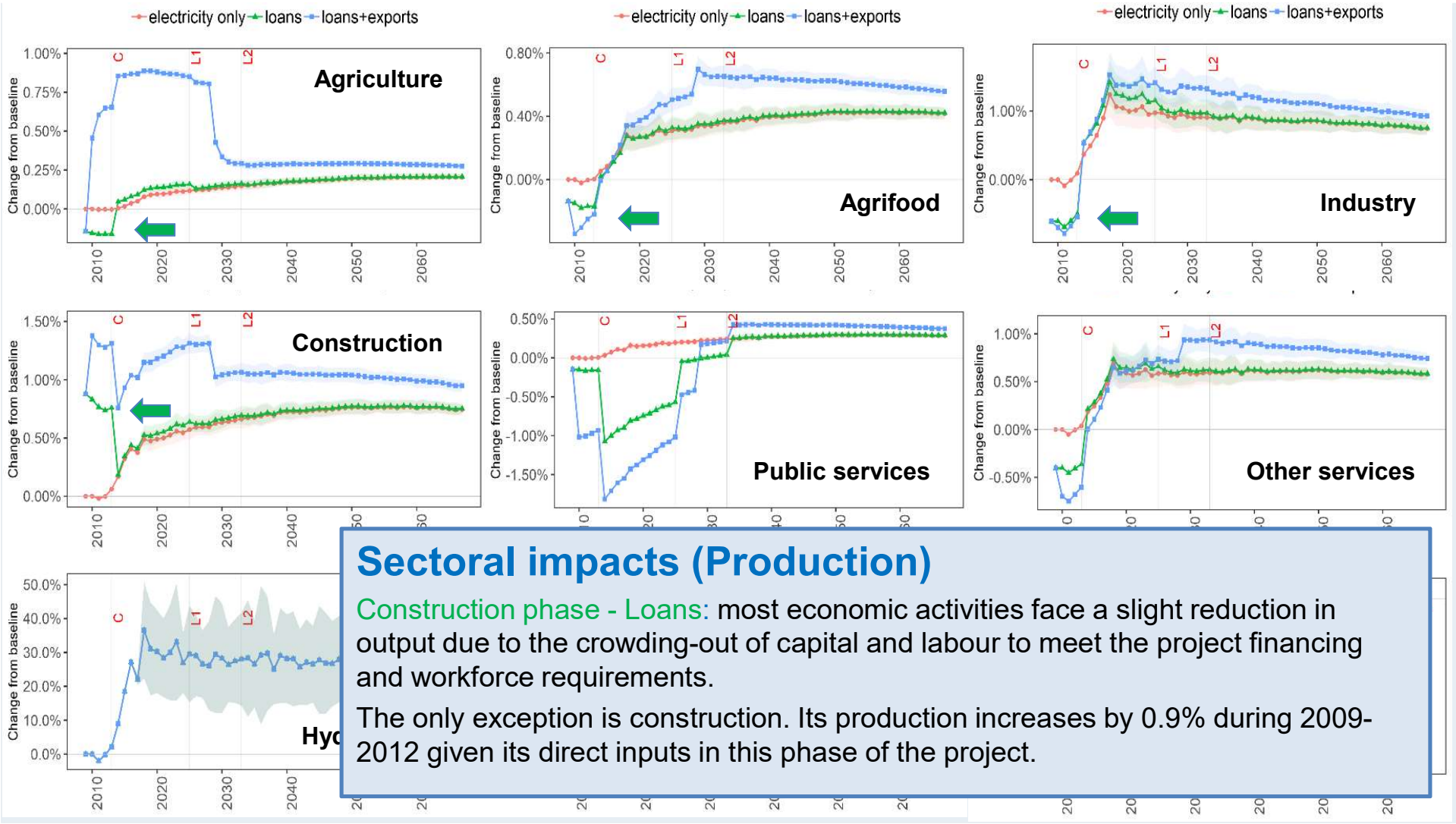






Sectoral impacts (Production)

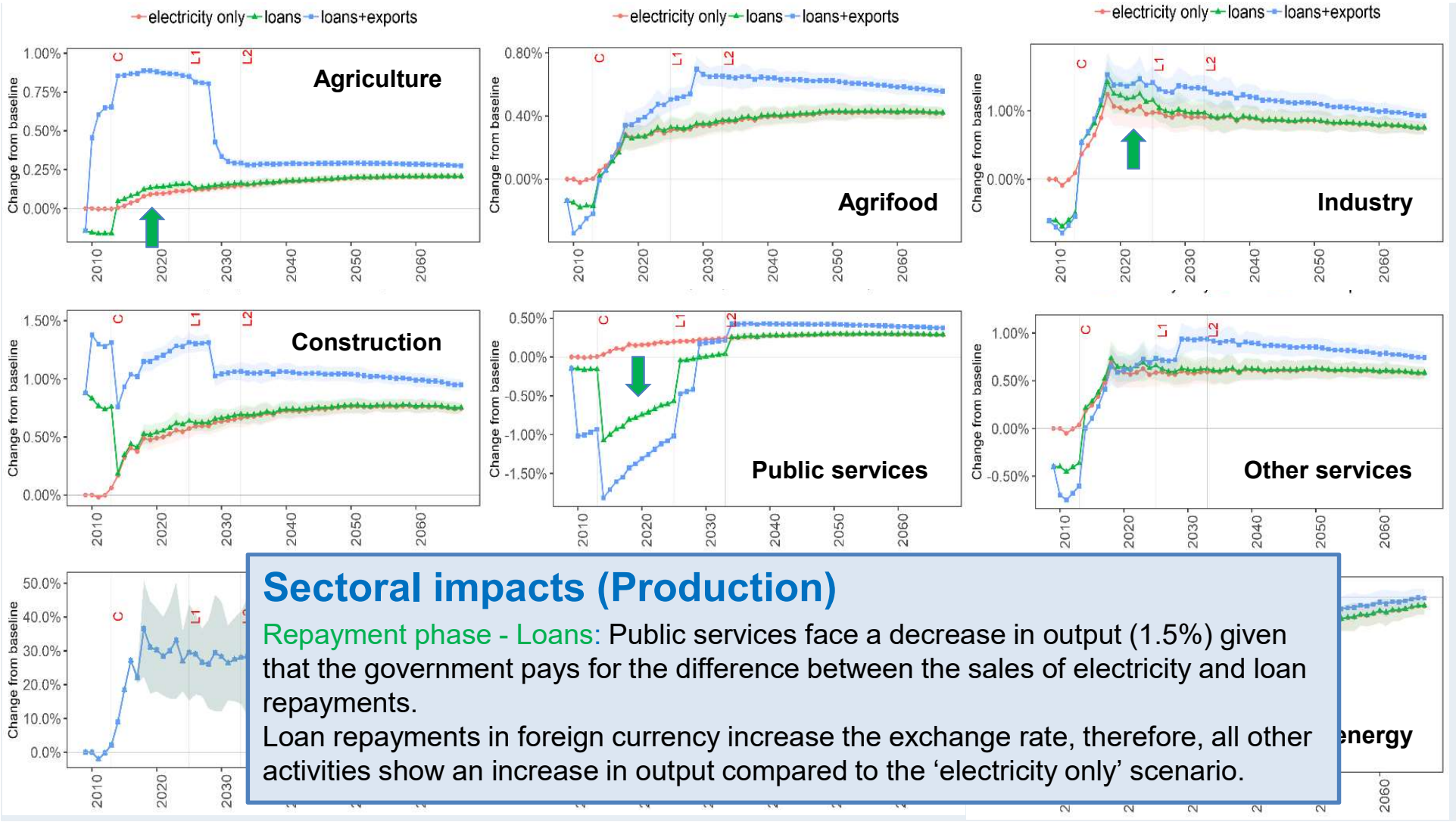
Electricity only: Higher electricity availability has a positive impact in all economic activities (industry and services), with the exception of non-hydro and other energy commodities



Sectoral impacts (Production)

Construction phase - Loans: most economic activities face a slight reduction in output due to the crowding-out of capital and labour to meet the project financing and workforce requirements.

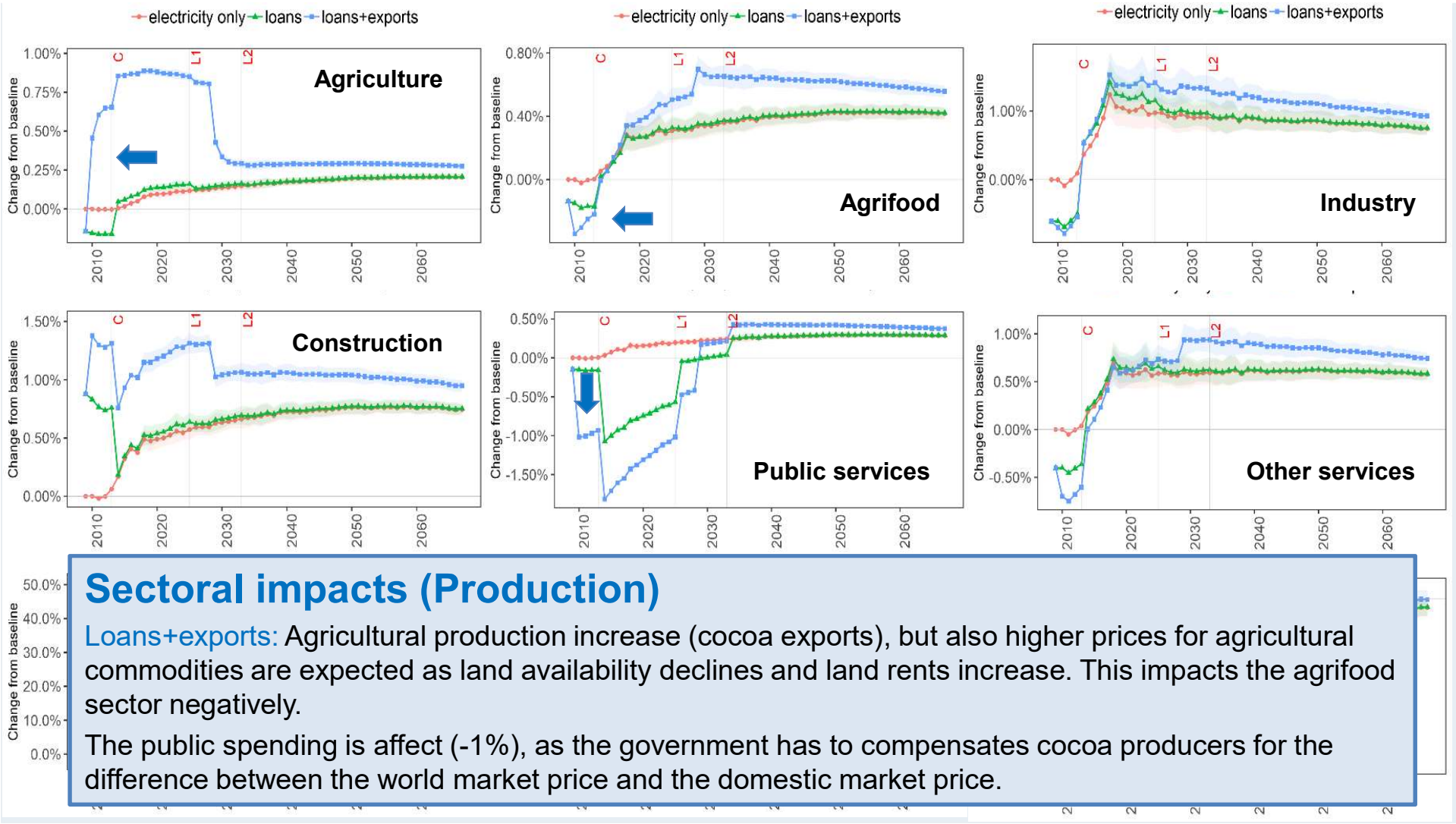
The only exception is construction. Its production increases by 0.9% during 2009-2012 given its direct inputs in this phase of the project.



Sectoral impacts (Production)

Repayment phase - Loans: Public services face a decrease in output (1.5%) given that the government pays for the difference between the sales of electricity and loan repayments.

Loan repayments in foreign currency increase the exchange rate, therefore, all other activities show an increase in output compared to the 'electricity only' scenario.



Sectoral impacts (Production)

Loans+exports: Agricultural production increase (cocoa exports), but also higher prices for agricultural commodities are expected as land availability declines and land rents increase. This impacts the agrifood sector negatively.

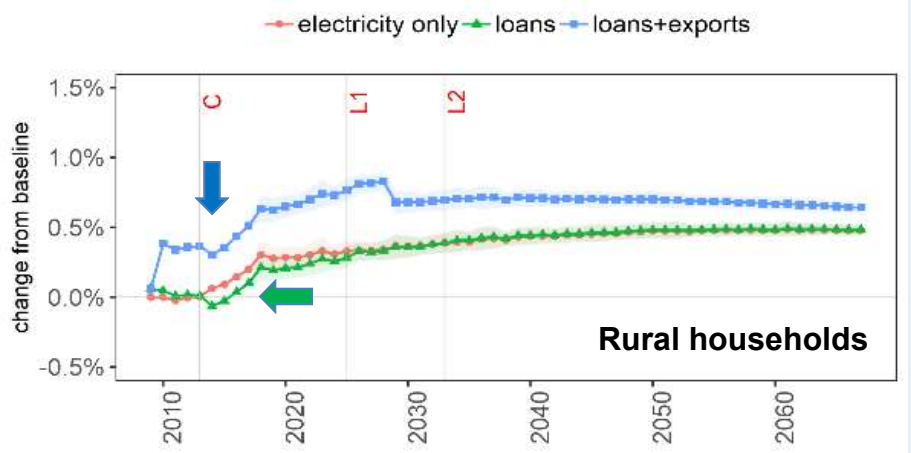
The public spending is affect (-1%), as the government has to compensates cocoa producers for the difference between the world market price and the domestic market price.

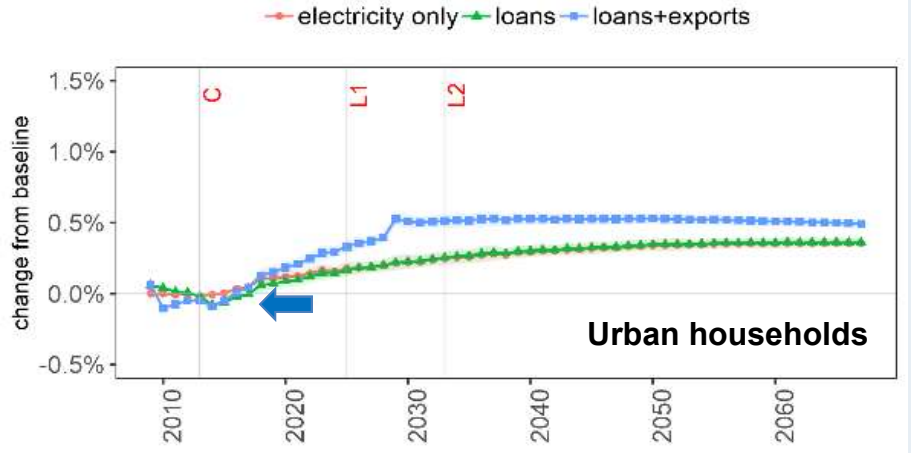
Household impacts: Consumption expenditure

The electricity only scenario has a slightly higher impact on the income and expenditure of the rural households compared to that of urban households.

The loans scenario shows a reduction in the income and expenditure of all households during the dam filling phase and only a marginal effect in the long run.

Under the loans+exports scenario, expenditure of urban households decreases up to 2018 given lower revenues from employment and non-agricultural capital.
At the same time, the income of rural households increases due to higher agricultural production and higher land rents.





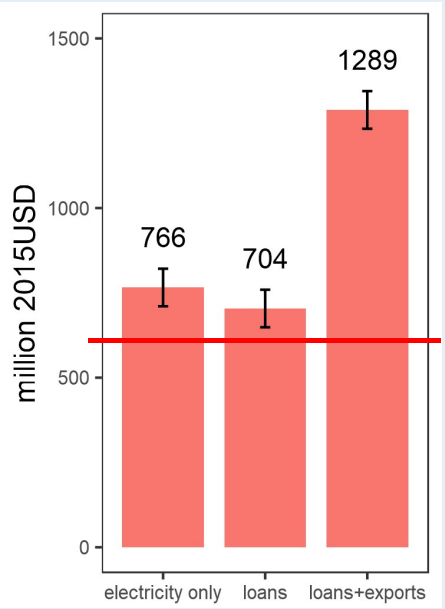
Cumulative economic impacts 2009-2067 (10% discount rate)

The mean cumulative impacts in all scenarios are comparable or considerably higher than the initial value of the project (622 million USD).

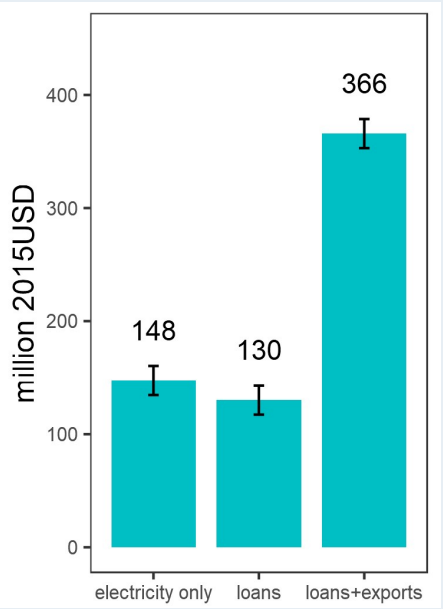
The real income effect is higher for rural households than urban household.

Under the loans+exports scenario the real income gains are even larger for rural households

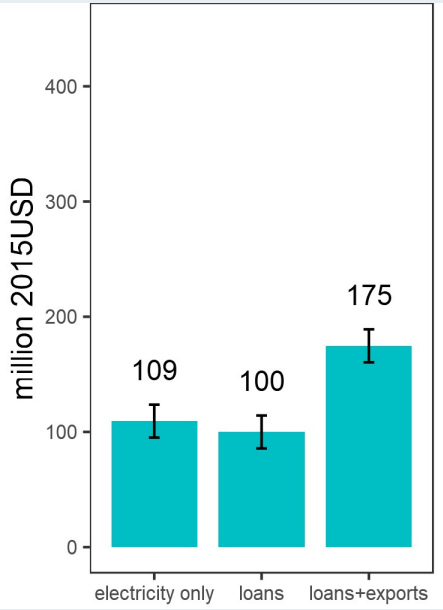
Cumulated GDP



Rural households Cumulated real income



Urban households Cumulated real income



Conclusions

- We coupled a CGE and a water system model to quantify the economy-wide impacts of hydropower development across project **construction, financing, and operation**
- Results demonstrate that the **inclusion of the construction and financing phases**, as well as the consideration of other macro-economic drivers (factor supply, exchange rates and public spending), changes both the cumulative value and the temporal evolution of the economic gains and losses of large infrastructure projects
- The inclusion of the financing conditions for the Bui Dam leads to a **68% increase** in mean discounted GDP gains (from 766 million USD in the 'electricity only' scenario to 1,289 million USD in 'loans+exports' scenario). This increase is driven by the additional economy-wide benefits of higher cocoa production.
- Therefore, we support the literature claiming that an economy-wide approach that goes **beyond the quantification of the direct impacts** of projects is appropriate for ex-ante economic assessments of infrastructure investments.

Thank you!