The systemic economic impacts of climate anomalies on agriculture: an integrated assessment framework

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Outline

- ✓ Motivation and objectives
- ✓ Modeling strategy
- ✓ Preliminary results

This is an ongoing study whose purpose is to make an economic assessment of climate anomalies (mainly droughts) in Brazil

For agriculture, not only does climate change have the potential to modify the agricultural use, but also the climate itself is a direct input for crop production

In 2005, several regions in Brazil experienced expressive reduction in precipitation compared to the historic average

- Southwest of Amazonia and Pará
- Sertao of Northeast (Ceará, Rio Grande do Norte, Paraíba and Pernambuco
- South of Brazil (Rio Grande do Sul, Santa Catarina and Paraná)

As the agriculture sector has important forward linkages in the Brazilian productive structure, climate anomalies, even spatially concentrated, can imply in damages for the whole country

The aim of this paper is to use a methodological framework in which physical and economic models are integrated for evaluating the economic impact of climate anomalies

Physical models can provide estimates about the **direct impact** of climate anomalies on the quantum of agriculture production. It is possible to integrate these models with economic general equilibrium models (CGE models) to account for the **systemic impact** of climate anomalies considering the linkages of the agriculture sector with the other sectors in the economy

Objectives:

(i) Build an integrated framework using physical models and CGE models that allow dealing with climate anomalies in a systemic context

(ii) Evaluate the extent to which climate anomalies impact the economic system

What is the cost of climate anomalies such as those in 2005 to the economy?

What sectors and regions are chiefly affected and to what extent?

The physical model estimated uses production function approach for the agriculture sector

We use the **profit function approach** to estimate short-term impacts of climate on agricultural production [Jehle e Reny, 2000; Mas-Collel et alli, 2006; Lau, 1978][1]. This approach assumes:

* Farmers allocate their inputs for the production of temporary crops and permanent crops;

* Farmers allocation decision: Profit maximization problem in a competitive market (exogenous prices);

* Inputs considered: Labor, Land, Fertilizers, and Energy.

*** Climate is considered as an input into the profit function: long-term climate (seasonal pattern) and climate variability (specific anomaly in the year).**

* Other fixed factors: soil type; investments; farmer education.

[1] JEHLE, G. A. ; P. RENY (2000) Advanced Microeconomics. Addison-Wesley: 2nd ed, pp. 138; MAS-COLLEL, A.; WHINSTON, M.l, GREEN, J. (1995) Microeconomic theory. Oxford: Oxford Uni. Press; Lau, L. J. (1978) "Aplications of profit functions" in Production Economics. North Holland, 1978

Database used to estimate the physical model

Agricultural data: Brazilian Agricultural Census of 2006 (IBGE).

Climate data: National Meteorology Institute (INMET)

Spatial scale: municipalities

Climate anomaly is defined as the difference between the observed value and the long-term average (for rainfall) divided by the standard deviation over the period

Drought Index: Rainfall anomaly below the long-term mean in two (2) standard deviations, by municipality *i* and season *S*:

$$DI_S^i < E(Rain_S^i) - 2\sigma_{Rain,S}^i$$

Strategy for sequential modeling integration

(i) The physical model was estimated for permanent and temporary crops using the Census dataset

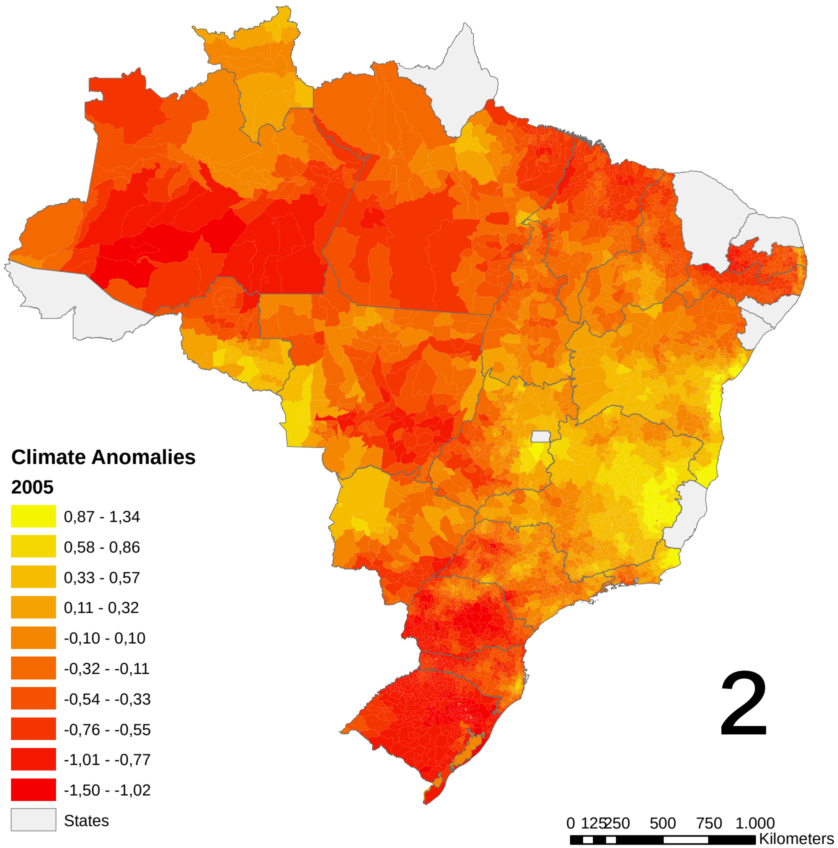
(ii) The model estimated was used to project the physical impact of climate anomalies for permanent and temporary crops in 2005 using climate and production data for this year

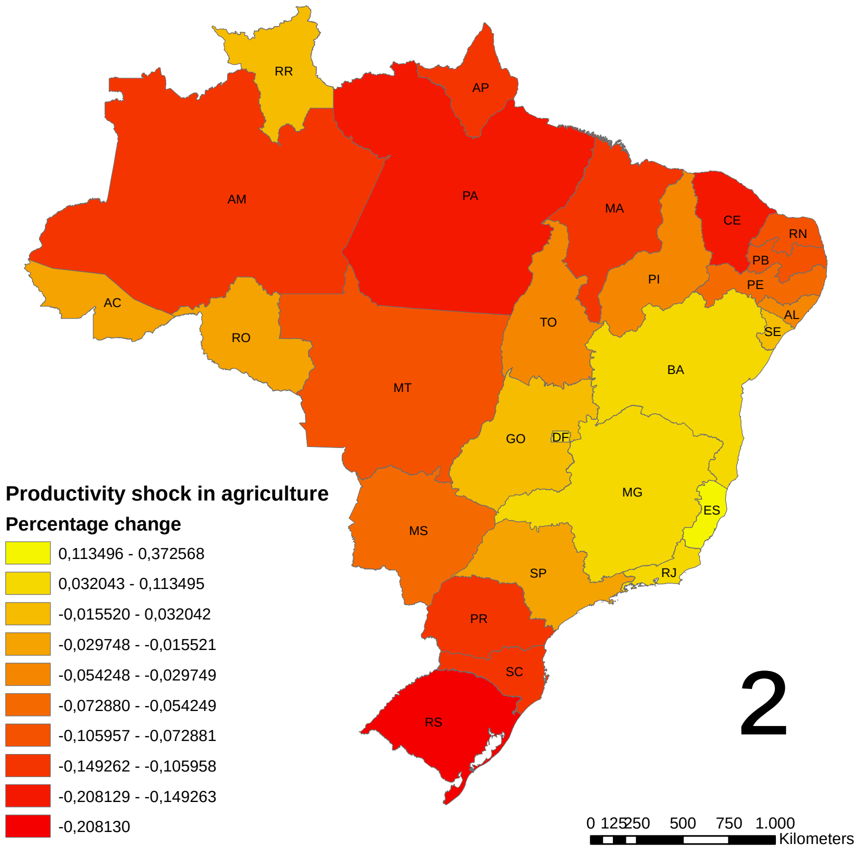
(iii) The total impact on agriculture production was calculated using the Laspeyres index whose weights were given by the shares of both permanent and temporary crops output for each municipality

(iv) These impacts were aggregated across the municipalities in each state to obtain a measure of the physical change in the agriculture production at the state level

(v) Such a measure was translated into a productivity shock in the agriculture sector in each state

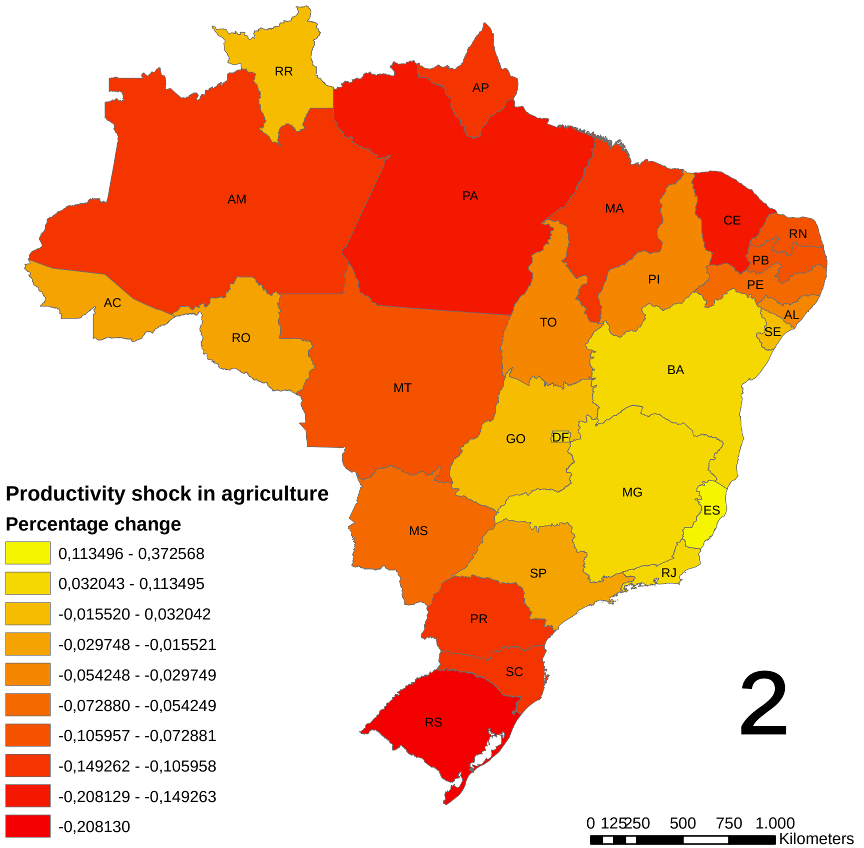
Climate anomalies for 2005 and their physical impact on agriculture production by state





Climate anomalies for 2005 and their physical impact on agriculture production by state

Regions/States		Productivity Shock
BRAZIL		**-3,7%**
North	RO	-1,6%
	AC	-2,0%
	AM	-13,0%
	RR	3,2%
	PA	-14,9%
	AP	-11,0%
	TO	-3,0%
Northeast	MA	-10,6%
	PI	-4,0%
	CE	-16,2%
	RN	-8,2%
	PB	-7,3%
	PE	-6,4%
	AL	-3,2%
	SE	2,4%
	BA	8,5%
Southeast	MG	10,2%
	ES	37,3%
	RJ	11,3%
	SP	-2,0%
South	PR	-12,4%
	SC	-10,9%
	RS	-20,8%
Center-West	MS	-5,4%
	MT	-7,9%
	GO	0,7%
	DF	9,4%



The integrated framework

"Physical" changes

Shocks in CGE variables

Climate anomalies → Changes in productivity by crops → All primary factor technical change in agriculture (regional shocks)

B-MARIA27 CGE Model (Haddad, 2007)

27 states

56 sectors

6 groups of economic agents

Short run closure

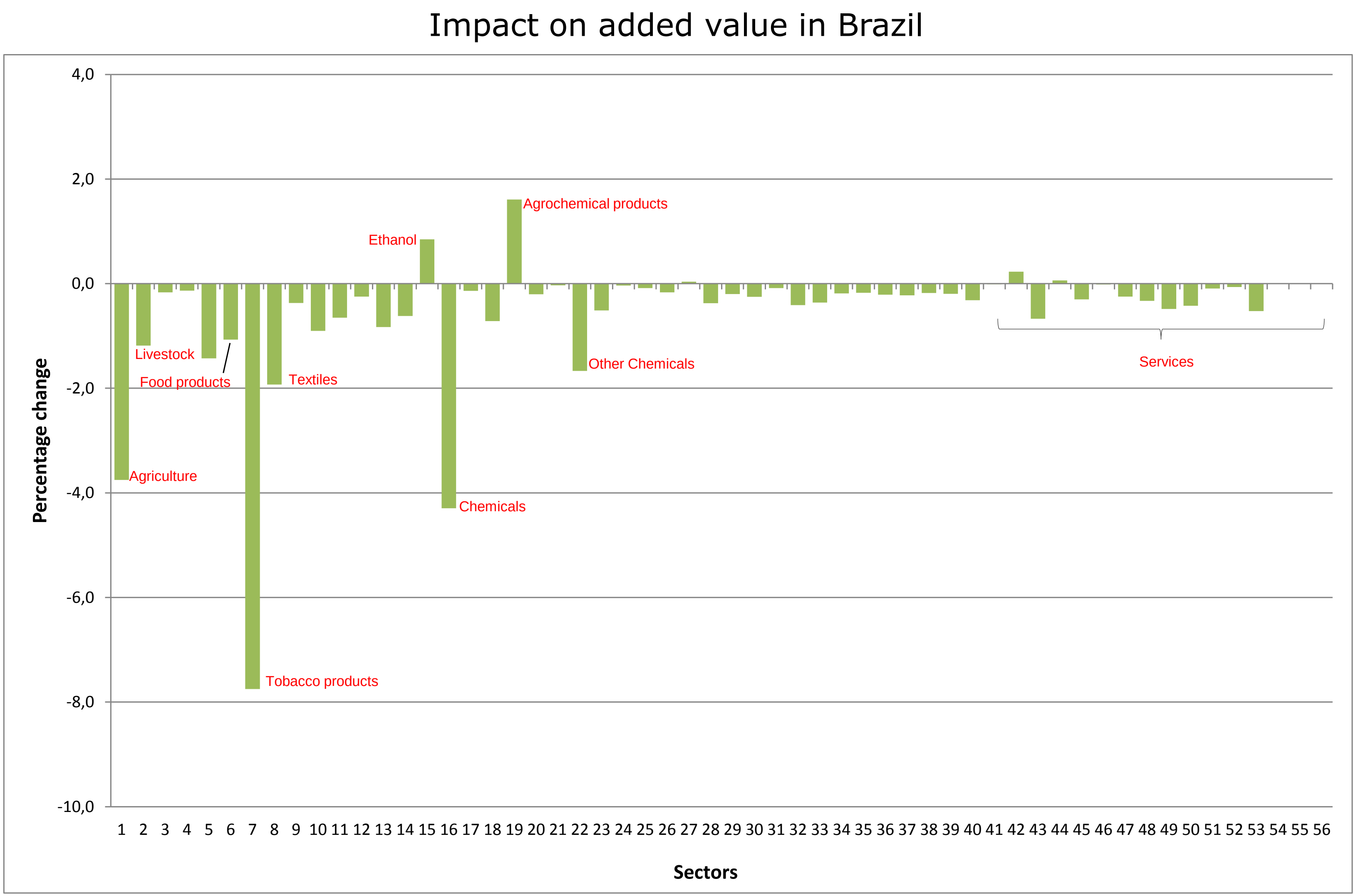
Simulation Results

The economic costs of 2005 climate anomalies accounted for **R$ 4,5 billions** (BRL 2011)

National results for macroeconomic variables and regional contributions

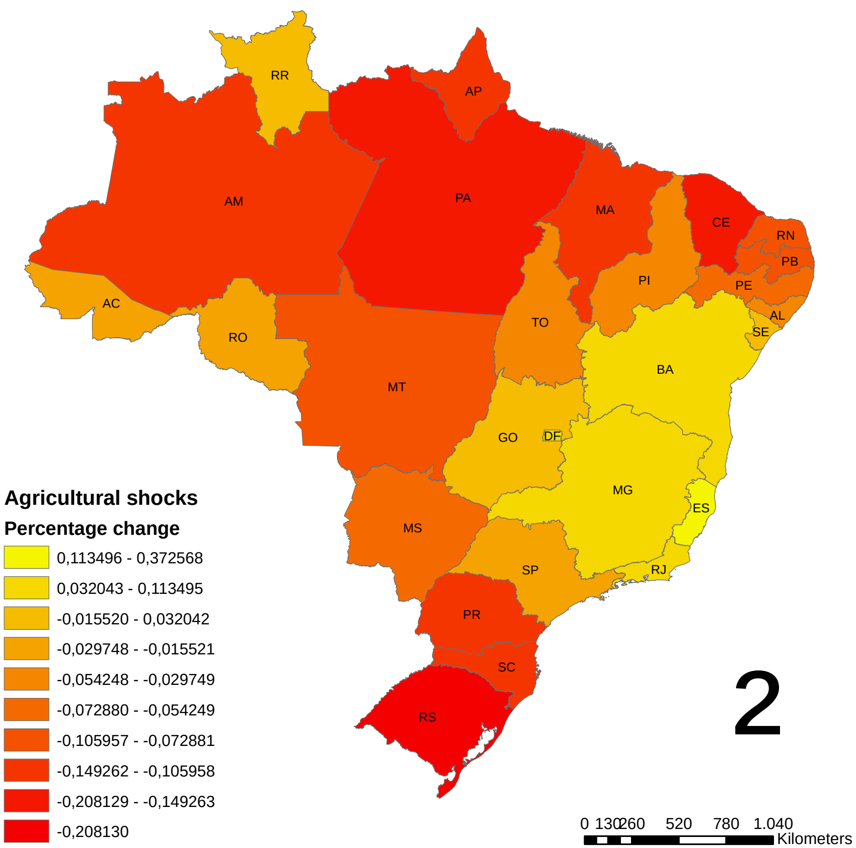
		GDP	Exports	Imports	Household Consumption
	BRAZIL	**-0,1630**	**-0,8190**	**-0,4810**	**-0,1629**
North	RO	-0,0010	-0,0035	-0,0006	-0,0009
North	AC	-0,0006	-0,0021	-0,0002	-0,0005
North	AM	-0,0080	-0,0298	-0,0014	-0,0063
North	RR	0,0014	0,0053	0,0015	0,0014
North	PA	-0,0434	-0,1659	-0,0249	-0,0365
North	AP	-0,0013	-0,0054	0,0002	-0,0008
North	TO	-0,0031	-0,0126	-0,0031	-0,0027
Northeast	MA	-0,0317	-0,1266	-0,0225	-0,0262
Northeast	PI	-0,0025	-0,0101	-0,0019	-0,0020
Northeast	CE	-0,0241	-0,0897	-0,0096	-0,0201
Northeast	RN	-0,0031	-0,0104	-0,0025	-0,0032
Northeast	PB	-0,0007	0,0011	-0,0013	-0,0016
Northeast	PE	0,0038	0,0214	-0,0012	0,0008
Northeast	AL	-0,0033	-0,0145	-0,0016	-0,0023
Northeast	SE	0,0019	0,0070	0,0011	0,0016
Northeast	BA	0,0494	0,2017	0,0235	0,0374
Southeast	MG	0,0619	0,3108	0,0492	0,0364
Southeast	ES	0,0837	0,4683	0,0336	0,0311
Southeast	RJ	0,0040	0,0136	0,0063	0,0046
Southeast	SP	-0,0238	-0,1024	-0,0329	-0,0209
South	PR	-0,0313	-0,3048	-0,1979	-0,0151
South	SC	0,0002	-0,0165	-0,0530	-0,0058
South	RS	-0,1877	-0,8171	-0,1728	-0,1457
Center-West	MS	0,0021	-0,0195	-0,0149	0,0054
Center-West	MT	-0,0070	-0,1315	-0,0549	0,0102
Center-West	GO	0,0002	0,0034	0,0024	-0,0001
Center-West	DF	0,0010	0,0106	-0,0014	-0,0012

There are spillover effects associated with the intersectoral linkages of the economy

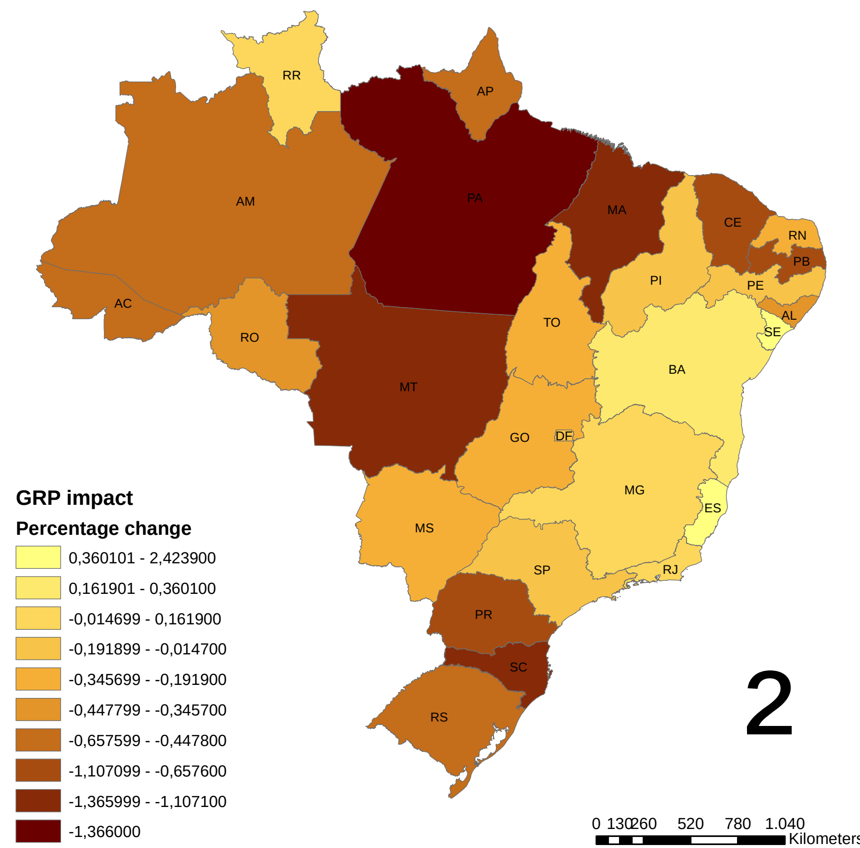


Regional results

Shocks on agriculture sector



Impact on Gross Regional Product



Interregional linkages among states seem to play a role for spreading the economic impact of climate anomalies

Impact on Gross Regional Product by origin of the climate shocks

	Total	RO	AC	AM	RR	PA	AP	TO	MA	PI	CE	RN	PB	PE	AL	SE	BA	MG	ES	RJ	SP	PR	SC	RS	MS	MT	GO	DF
RO	**-0,346**	-0,082	-0,001	-0,029	0,000	-0,009	-0,002	-0,001	-0,006	-0,001	-0,007	0,000	0,004	0,009	-0,002	0,001	0,023	0,031	0,014	0,003	-0,027	-0,107	-0,013	-0,107	-0,009	-0,029	0,001	-0,001
AC	**-0,448**	0,004	-0,117	0,020	0,001	0,063	0,003	0,000	0,024	0,002	0,020	0,007	0,013	0,021	-0,002	-0,001	-0,051	0,016	-0,004	0,002	-0,025	-0,303	-0,011	-0,054	-0,039	-0,039	0,003	-0,001
AM	**-0,498**	0,001	0,000	-0,344	0,003	-0,003	0,001	-0,001	-0,002	0,000	0,003	0,001	0,004	0,006	-0,001	0,000	-0,009	0,006	-0,003	0,001	-0,009	-0,072	-0,002	-0,052	-0,009	-0,019	0,001	0,000
RR	**0,162**	0,001	0,000	-0,015	0,177	0,007	0,000	0,007	0,051	0,002	-0,009	-0,002	0,003	0,007	-0,003	0,001	0,040	0,033	0,029	0,004	-0,030	-0,076	0,003	-0,028	-0,011	-0,025	-0,001	-0,001
PA	**-1,366**	0,002	0,001	0,014	0,001	-0,936	-0,001	-0,002	-0,014	-0,001	0,006	0,006	0,020	0,032	-0,005	0,001	-0,018	0,040	0,016	0,004	-0,041	-0,271	-0,008	-0,155	-0,029	-0,029	0,003	-0,001
AP	**-0,511**	0,000	0,000	0,000	0,001	-0,028	-0,290	-0,002	-0,016	-0,001	-0,010	-0,001	0,002	0,005	-0,002	0,001	0,018	0,024	0,010	0,004	-0,020	-0,062	-0,007	-0,124	-0,003	-0,007	0,001	-0,001
TO	**-0,192**	0,001	0,000	0,000	-0,004	0,028	0,000	-0,238	0,063	0,003	-0,001	-0,001	0,005	0,011	-0,003	0,001	0,036	0,019	0,019	0,003	-0,025	-0,081	-0,004	0,020	-0,012	-0,032	-0,001	0,000
MA	**-1,107**	0,002	0,001	0,015	-0,004	0,052	0,002	0,007	-0,980	0,001	0,044	0,006	0,014	0,012	0,000	-0,002	-0,036	-0,030	-0,036	-0,001	-0,004	-0,176	-0,013	0,102	-0,029	-0,057	0,001	0,001
PI	**-0,142**	0,001	0,000	0,005	-0,001	0,014	0,001	0,001	0,009	-0,113	0,001	0,002	0,010	0,014	-0,003	0,001	-0,003	0,019	0,011	0,003	-0,019	-0,088	-0,006	-0,004	-0,007	0,012	0,001	-0,001
CE	**-0,726**	0,000	0,000	-0,001	0,002	-0,018	0,000	-0,003	-0,031	-0,004	-0,526	-0,002	0,014	0,020	-0,005	0,002	0,037	0,031	0,017	0,004	-0,024	-0,058	-0,006	-0,142	-0,003	-0,027	0,001	-0,001
RN	**-0,232**	0,000	0,000	0,000	0,001	-0,008	0,000	-0,002	-0,018	-0,002	-0,002	-0,122	0,021	0,022	-0,004	0,001	0,010	0,019	0,010	0,002	-0,015	-0,048	-0,003	-0,093	-0,003	0,002	0,000	0,000
PB	**-0,829**	-0,002	-0,001	-0,013	0,005	-0,093	-0,002	-0,010	-0,096	-0,010	-0,090	-0,019	-0,278	0,100	-0,027	0,009	0,194	0,109	0,087	0,011	-0,069	-0,113	-0,015	-0,401	-0,002	-0,103	0,002	-0,002
PE	**-0,074**	0,000	0,000	-0,004	0,001	-0,023	-0,001	-0,002	-0,022	-0,002	-0,017	-0,001	0,032	-0,027	-0,008	0,002	0,028	0,027	0,024	0,003	-0,015	-0,026	-0,006	-0,066	0,002	0,029	0,000	0,000
AL	**-0,366**	-0,001	0,000	-0,003	0,002	-0,033	-0,001	-0,004	-0,042	-0,004	-0,012	-0,005	-0,020	-0,025	-0,113	0,004	0,042	0,023	0,020	-0,001	0,003	-0,008	-0,005	-0,145	-0,008	-0,031	0,001	-0,001
SE	**1,818**	0,004	0,002	0,023	-0,008	0,117	0,003	0,013	0,122	0,007	0,045	0,004	0,013	0,014	-0,005	0,092	-0,093	-0,110	-0,041	-0,014	0,170	0,088	-0,131	1,545	-0,050	0,006	0,002	0,001
BA	**0,360**	0,000	0,000	0,000	0,003	-0,018	0,000	-0,005	-0,034	-0,003	-0,014	0,001	0,016	0,026	-0,008	0,001	0,588	0,042	0,042	0,006	-0,033	-0,121	-0,017	-0,192	-0,001	0,083	-0,001	-0,001
MG	**0,055**	-0,001	-0,001	-0,007	0,003	-0,050	-0,001	-0,005	-0,045	-0,003	-0,025	-0,004	-0,001	0,003	-0,003	0,002	0,038	0,398	0,048	0,007	-0,032	-0,049	-0,021	-0,246	0,007	0,045	0,000	0,000
ES	**2,424**	-0,002	-0,001	-0,014	0,004	-0,084	-0,002	-0,007	-0,072	-0,006	-0,047	-0,006	0,001	0,010	-0,007	0,004	0,114	0,108	2,939	0,015	-0,054	-0,064	-0,018	-0,391	0,008	-0,002	0,000	-0,002
RJ	**0,059**	0,000	0,000	0,000	0,000	-0,002	0,000	0,000	-0,001	0,000	-0,003	0,000	0,000	0,001	0,000	0,000	0,003	0,006	0,008	0,010	0,002	0,008	0,004	0,025	-0,001	-0,001	0,000	0,000
SP	**-0,052**	0,000	0,000	-0,003	0,000	-0,017	-0,001	-0,001	-0,010	-0,001	-0,009	-0,002	-0,002	-0,001	-0,001	0,001	0,015	0,010	0,015	0,001	-0,021	0,011	-0,003	-0,046	0,003	0,011	0,000	0,000
PR	**-0,658**	-0,002	-0,001	-0,015	0,003	-0,075	-0,002	-0,006	-0,063	-0,005	-0,034	-0,005	-0,001	0,003	-0,004	0,003	0,080	0,068	0,041	0,004	-0,056	0,009	0,159	-0,768	0,013	-0,003	0,000	-0,001
SC	**-1,190**	-0,003	-0,002	-0,019	0,010	-0,128	-0,003	-0,017	-0,145	-0,010	-0,048	-0,006	-0,003	0,002	-0,004	0,002	0,113	0,122	0,068	0,012	-0,112	-0,271	-0,074	-0,675	0,031	-0,030	0,001	-0,002
RS	**-0,508**	0,001	0,001	0,003	-0,004	0,033	0,001	0,006	0,052	0,003	0,007	0,000	-0,001	-0,001	0,001	0,000	-0,007	-0,019	-0,005	-0,002	0,015	0,041	-0,007	-0,615	-0,005	-0,005	-0,001	0,000
MS	**-0,256**	-0,001	-0,001	-0,010	0,003	-0,048	-0,001	-0,004	-0,044	-0,003	-0,016	-0,003	0,000	-0,002	-0,002	0,001	0,031	0,018	0,014	0,004	-0,027	0,039	-0,014	-0,178	-0,053	0,042	-0,002	0,000
MT	**-1,146**	-0,002	-0,001	-0,021	0,002	-0,054	-0,003	-0,003	-0,041	-0,003	-0,029	-0,003	0,011	0,015	-0,006	0,002	-0,026	0,060	0,037	0,008	-0,058	0,038	0,023	-0,240	0,068	-0,915	-0,007	0,003
GO	**-0,280**	-0,001	-0,001	-0,007	0,002	-0,048	-0,002	-0,005	-0,037	-0,003	-0,018	-0,003	0,002	0,003	-0,002	0,001	0,040	0,072	0,031	0,006	-0,037	-0,096	-0,018	-0,188	-0,002	0,014	0,012	0,004
DF	**-0,015**	0,000	0,000	-0,002	0,000	-0,009	0,000	-0,001	-0,007	-0,001	-0,005	-0,001	0,000	0,001	-0,001	0,000	0,008	0,004	0,008	0,001	-0,006	-0,002	-0,005	-0,034	0,002	0,001	0,000	0,031

Further research

(i) Further disaggregate the physical model to include different permanent and temporary crops

(ii) Try to include spatial effects in the econometric specification

(iii) Simulate the climate shocks for both agriculture and livestock production

(iv) Given the heavy reliance on hydro power plants it is also important to take into account the effects of climate shocks on electricity generation

(v) Implement sensitivity analysis of variations in the key parameters that drive the CGE model results

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