The Climate Change Effects on the Agricultural Sector of Bolivia

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Abstract

Bolivia as many other countries in the world, it is looking for some mechanism that allows to fight against the adverse impacts produced by climate variability. There is consensus that more adaptation and mitigation measures if we want to reduce the adverse effects produced by the climate change - in addition the vulnerability[1] to these phenomena depends also on other stress factors.

The aim of our research seeks to evaluate the economic impact of climate change in the agricultural sector of Bolivia with and without mitigation measures. From one hand the work quantify the effect of climate change over the GDP – from the other hand it evaluates the relevance of mitigation measures destined to reduce the risk and vulnerability of climate change.

There are many methodologies that evaluate the incidence of climate change, both from economic and technological perspective – the first one in well known as bottom-up schemes – the second one is named top-down schemes. For the purposes of our research we use top-down model, based on Computable General Equilibrium (CGE) techniques.

Key words: Climate Change, Agricultural Sector, General Equilibrium Model.
JEL Classification: O13, C68

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[1] Vulnerability is a function of exposure to climate factors, sensitivity to change and capacity to adapt to that change.

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1. Introduction

All the countries in the world are currently searching for mechanisms that allow to fight against the adverse impacts produced by climate variability. It is evident that Bolivia like many other countries require more adaptation[2] and mitigation[3] measures in order to reduce the effects produced by the climate change[4]. In addition, the vulnerability to this phenomenon depends also on other stress factors.

Since financial resources are destined to diminish the climate change effects, the subject becomes an important issue for any economy – specially in sectoral policy design. The analysis seeks to identify the propagation mechanisms, because the relationship between economy and environment does not necessarily have a direct path - it often depends on indirect effects (e.g. social vulnerability) and the interaction between the economic production functions and environmental constraints helps to identify and quantify the adaptation (mitigation) costs versus non-adaptation (mitigation).

With this framework, the aim of our research is to evaluate the economic impact of climate change in the Bolivian agricultural sector with and without mitigation measures. On the one hand the work quantifies the effect of climate change over the GDP – on the

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[2] The Intergovernmental Panel on Climate Change (IPCC 2007), defines adaptation as the “adjustment in natural or human systems in response to actual or expected climate stimuli or their effects, which moderates harm or exploits beneficial opportunities”.

[3] Mitigation is understood as the prevention of carbon emissions promoting the reduction of greenhouse gas emission, efficient use of energy and other resources or politics that norm the ground usage promoting sustainability.

[4] "Climate Change" means a change of climate conditions, which is attributed directly or indirectly to human activity and alters the composition of the global atmosphere and which occurs in addition to natural climate variability observed over comparable time periods.

other hand it evaluates the relevance of mitigation measures destined to reduce the risk and vulnerability of climate change.

There are many methodologies which evaluate the incidence of climate change, both from an economic and a technological perspective – the first are well known as bottom-up schemes – the latter are named top-down schemes. For the purposes of our research we use a top-down model, based on Computable General Equilibrium (CGE) techniques.

This kind of models compare two different equilibriums - a base line equilibrium with an *ex-post* equilibrium produced by an external shock (e.g. change in the scale of agricultural production). With this tool we compared the economic paths in the short and medium term under three different simulation scenarios for the agricultural production (i.e. normal, moderate and pessimistic) and two different closures (i.e mitigation and non-mitigation).

The document has the following structure – in section 2, we describe the economics of the agricultural sector. In the section 3, we describe the Bolivia Agricultural Sector. In section 4, we introduce the theoretical basis of CGE. In section 5, we analyze the results of the model. In section 6, we analyze the results of simulation experiments with mitigation and non-mitigation scenarios. Finally, in section 7, we present our conclusions.

2. The Economic View of Climate Change: Agricultural Sector

Agriculture is an economic activity that is highly dependent upon weather and climate in order to produce the food and fibre necessary to sustain human life. Not surprisingly, agriculture is deemed to be an economic activity that is expected to be vulnerable to climate variability and change. The vulnerability of agriculture to climate variability and change is an issue of major importance to the international scientific community. This concern is reflected in Article 2 of the UNFCCC, which calls for the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent serious anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to: (i) allow ecosystems to adapt naturally to climate change; (ii) ensure that food production is not threatened; and (iii) enable economic development to proceed in a sustainable manner.

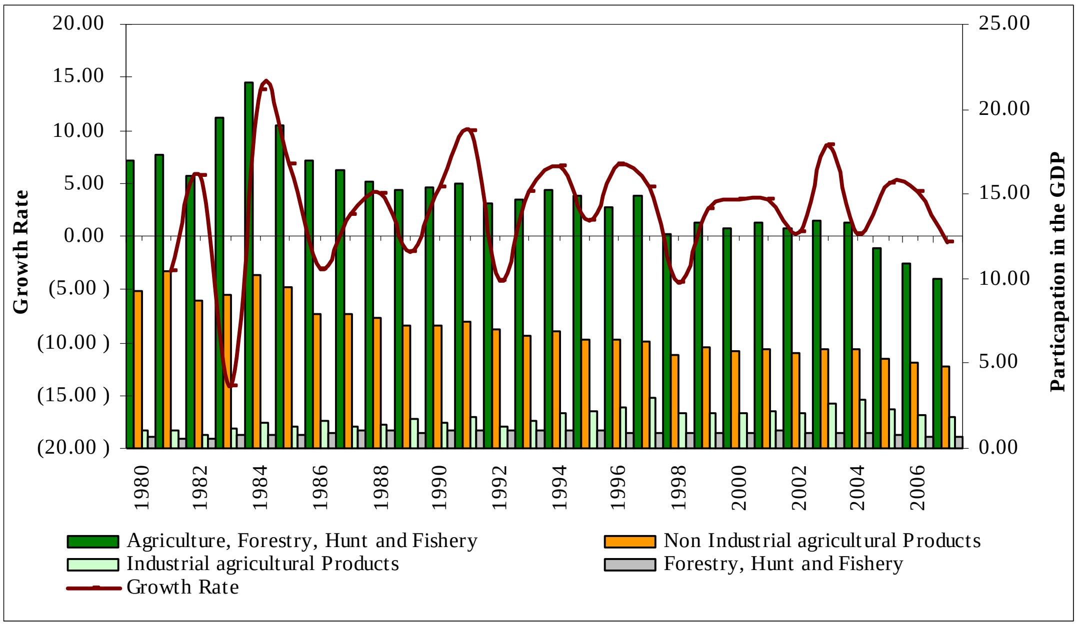
On a global basis, climate variability and change may have an overall negligible effect on total food production (Parry and Rosenwieg, 1993); however, the regional impacts are likely to be substantial and variable, with some regions benefiting from an altered climate and other regions adversely affected. Generally, food production is likely to decline in most critical regions (e.g. subtropical and tropical areas), whereas agriculture in developed countries may actually benefit as technology is more available and if appropriate adaptive adjustments are employed.

Agriculture is one of the oldest economic activities. This is because it is the backbone of our food supply and without it the world's population would experience food insecurity. For this reason any effect that climate change has on agriculture will be passed on to society. Since agriculture is also dependent on the natural resource base, changing climate will require the adaptation of agricultural practices that accommodate the new climate while conserving the natural resource base.

3. The Agricultural Sector of Bolivia

The agricultural sector is the second most important economic activity with a growth average of 2.4% – the share in the GDP reached 15% during the last 25 years, with an incidence of 0.45% (See Figure 1). In this secction we analyse the industrial and non-industrial agricultural production – the first one has an average contribution of 2% during the period 1980-2007, the second one is close to 7%.

Figure 1: Agricultural GDP Behavior 1980 – 2007

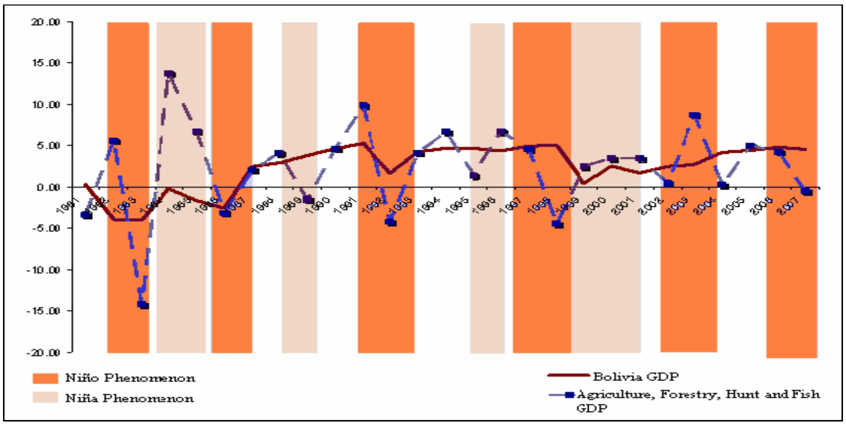


Source: Own elaboration with data from INE (National Statistics Institute).

The country has suffered from many climatologic phenomena (See Figure 2). Their incidence over the agricultural GDP is evident – they lower the production, specially in the years 1983, 1987, 1993, 1989 and 2007, with strong events like "El Niño"[5]. Only in 2003 "El Niño" was considered weak. We expect more intense chronic and extreme climate events during the next years, with serious effects on food production and food security, i.e. through temperature changes and rain precipitation increases (Easterling, et al., 2007, Stern Review 2007).

[5] The Niño/Niña phenomena are incidents in which extreme climate variability occurs.

Figure 2: The Incidence of the “Niño/Niña” Phenomena in the Agricultural GDP Growth Percentages 1991 - 2007



Source: Own elaboration with data from INE (National Statistics Institute).

3.1.The employment contribution

The overall agricultural sector employs on average 39% of the total occupied population, between 1999-2006 the percentage reached 80% in the rural area (See Table 1). According to UDAPE (2006), the structure and the dynamics of employment have changed due to the sprouting of new enterprise units during the nineties.

Table 1:
Percentage of Occupied Population in Rural Area
By Economic Activity 1999 – 2006.

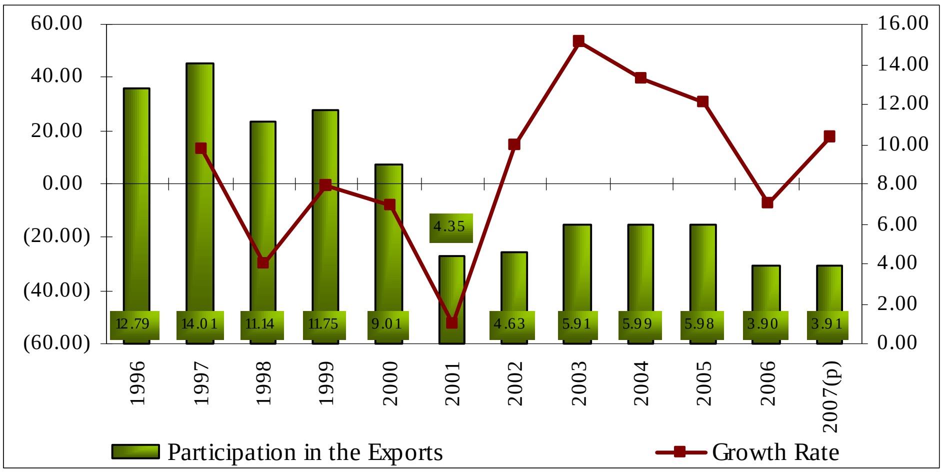
Year	1999	2000	2001	2002	2003-2004(1)	2005	2006
Agriculture, Forestry and Hunt	39.54	38.6	44.12	42.26	34.52	38.28	39.23
Manufacturing industry	11.4	10.1	9.2	11.17	11.21	10.93	10.5
Services	16.22	16	14.78	14.2	16.43	14.78	14.23
Others	32.84	35.2	31.89	32.37	37.84	36	36.05
Agriculture, Forestry and Hunt	84.13	84.4	84.99	86.79	70.78	81.07	82.45
Manufacturing industry	2.72	3.1	3.02	2.53	5.16	3.17	3.14
Services	2.94	3.1	2.88	2.93	5.81	3.51	2.81
Others	10.21	9.6	9.08	7.74	18.25	12.26	11.61

Source: Own elaboration with data from INE (National Statistics Institute)

3.2.The export contribution

The main non-traditional export products during the period 1980 – 2007 were soy and derivatives, coffee, cacao, sugar, rubber and cotton (see Figure 3), and their average contribution to total exports reached 16 %.

Figure 3: The Agricultural Export Behaviour 1996 - 2007



Source: Own elaboration with data from INE (National Statistics Institute)

4. The Bolivian General Equilibrium Model (CGE)

The General Equilibrium Model (CGE) is a tool designed to measure and evaluate the overall economic effects including second order effects – related to external shock or goverment policy intervention. This scheme aggregates numerically all market equilibrium conditions, whereby the model captures multiple simultaneous balances for different markets or sectors (e.g. the agricultural sector). Therefore the model surpasses any linear specifications (Shoven & Whalley 1992; Ginsburgh & Keyser 1997; Dixon et al. 1982; and Horridge, et al. 1993).

New computacional advances introduced more programming posibilities to reproduce the economic functioning by simulating partial or general equilibrium. We use in this research a dynamic third generation CGE model with the purpouse to evaluate macroeconomic and sectoral effects (agricultural sector) in the short and medium term (Pereira & Shoven, 1988; Decaluwé & Martens, 1988).

The closures of our model verify the neoclasical macroeconomic restructuring of portfolio assets, sectoral production changes and income distribution - in different scenarios, like structural adjustment and policy planning (Bourguignon et al., 1989; Rosenzweig & Taylor, 1990 & Jemio, 1993, 2001a,b). It also combines the assumption of optimal consumption and portfolio composition – following the recommendation of Agénor et al. (2002); Heathcote (1998) & Silva (2004).

4.1.The Markets: Goods and Factors

These two markets (goods and factors) were modelled following conventional assumptions of the CGE literature. The first one states that capital remains fixed in the short term, the second one assumes that technology has Constant Elasticity of Substitution (CES) for some specific production sectors (i.e. agricultural, petroleum, natural gas, mining and services).

The third one is the small country (price taker) assumption for productive sectors (i.e. agricultural, petroleum, natural gas, mining and services). Therefore, any gap between supply and demand adjusts through commercial flows (Armington, 1969). According to the fourth assumption, the CES function also determines the capital demand, the labour and the imported inputs in these sectors.

The fifth assumption defines that the market structure for other sectors (i.e. manufacture and construction) is based on oligopolistic rules. The sixth assumption declares the existence of two sectors (i.e. urban and informal services), ruled by *mark-up*, because of their excess of installed capacity. The seventh assumption states that imports and exports demands are perfectly elastic. Finally, the capital goods are a fix share of the total investment in the base year and the consumer goods imports are determined by a Linear Cost System (LCS).

4.2.The Financial Sector

The model analyses the institutional and distributive relationship in the financial sector. For this purpose nine categories were defined (i.e. households, state companies, private companies, government, external sector, central bank, commercial banks, other financial institutions and pension funds). Taylor (1990), classify this kind of model as multi-sectorial and multi-institutional general equilibrium scheme of three-gaps.

According to the Social Account Matrix (SAM), every balance in the model satisfies the following relation “Total Assets = Total Obligations + Net Wealth” (Thiele & Piazolo, 2003). Hence, for each one of these institutions we require to define a portfolio behaviour. We also define five types of assets/obligations, each one of which has a different rate of return (i.e. physical capital, public assets/obligations, currency money, private assets/obligations and external assets/obligations).

Finally, the financial restrictions correspond to the patterns of each institution – given the household size the adjustment follows the rule ***save first –*** then invest. The effective level of investment and financial assets are adjusted to the availability of funds (profitability criteria). For private and public companies the rule is the opposite, investment ***first*** *and* then pays.

5. The Experiment Design

The design of any general equilibrium experiment has two main elements. The first one is the base year definition, which shows the economic behaviour over a stable year (without random shocks). The second one is the simulation scenario for one specific context. In this section we present the base year assumptions and the simulation scenarios that will be used to evaluate the effects of climate change (external production shock) in the agricultural sector of Bolivia.

5.1. The Base Line

The CGE model was built based on the SAM – 2004, because this is the last matrix constructed in Bolivia. Due to the lapsed time, it is required to validate the structural parameters of the CGE model (with econometric techniques) – in the rejecting case, it is necessary to calculate an adjustment rate to correct the model outcomes. The procedure concludes that the structural parameters are still valid - we also validate the specific agricultural production function for this experiment.

With this analysis, the basis of the experiment is the change in the parameter of the agricultural production function, regarding their sectoral activities (i.e. traditional agriculture, modern agriculture and coca). Concerning the Base Line (BL) scenario, two distortions were introduced – the first one is a shock in the agriculture production related to climate change effects (e.g. El Niño), the second one is an increase in the mitigation expenditures destined to reduce the risks and vulnerability of climate change.

Since the CGE model was built for macroeconomic analysis, the base year reflects mainly these kinds of trajectories. The base year assumptions are: (1) prices are exogenous for trade commodities, then the terms of trade and interest rates are given by world prices; (2) the Foreign Direct Investment (FDI) is the average behaviour of the last four years; (3) the government expenditures have a growth rate of 2.5% each year; (4) the government investment has a growth rate of 2.7%.

5.2.The Simulation Scenarios

The agriculture in developing countries is the most important and also vulnerable activity affected by climate change. In Bolivia, the sectoral share of agriculture is 10%[6] of the GDP, which makes it the third income activity in the country. The current experiments consider the effects of climate change under three scenarios:

(1) The normal scenario considers the average production in the agricultural sector during the last 19 years (2.46%). With this scenario strong adverse environmental changes are internalised.

(2) The moderate scenario considers the average production in the agricultural sector during the last five years (2.33%), with non-extreme climate change phenomena.

(3) The pessimistic scenario considers the average growth rate of the agricultural sector during the years with extreme climate change (-0.28%). The strong Niño and Niña correspond to the following years (1989, 1993, 1996, 1998, 2001 and 2007).

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[6] Annual Statistical review, INE (2007)

Finally, we carried out one policy closure on each one of the three scenarios – an increase in the mitigation expenditure of 10% by halves (i.e., Government Expenditures and Direct Investment) destined to reduce the risk and vulnerability to climate change.

6. The Experiments Results

6.1. Compared Scenarios

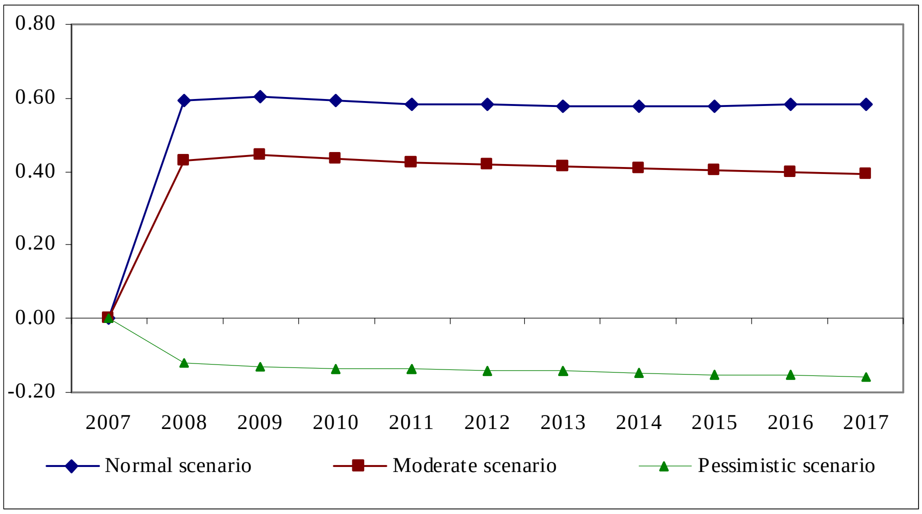
6.1.1. The Scenario without Mitigation

Within the normal and the moderate scenario, it is observed that Bolivian GDP will grow throughout the next 10 years at a rate superior to 0.5% and 0.35% per year respectively. In the absence of any adverse shocks in the agricultural sector, the pessimistic scenario shows a drop in the growth rate of -0.33% per year (See, Figure 4). It is evident that any drop in the agricultural production sector is translated mainly in employment reduction with the corresponding decrease in the real GDP.

6.1.2. The Scenario with Mitigation

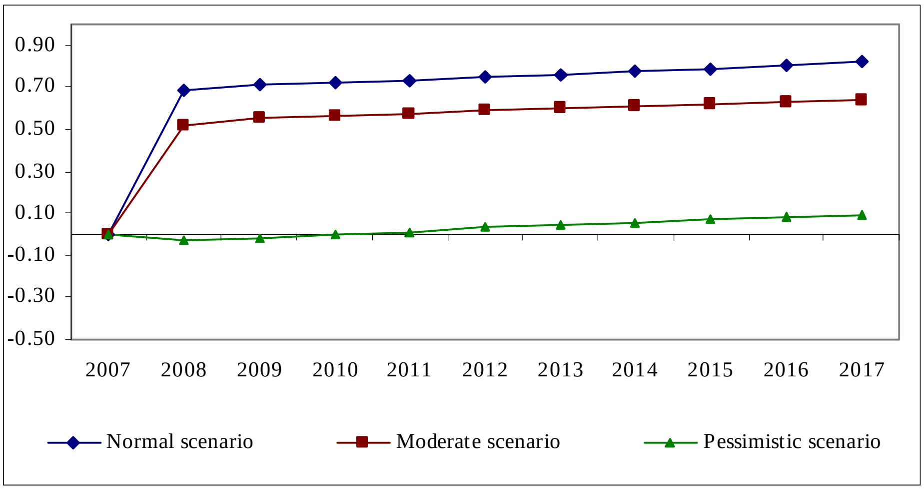
In this experiment, given the same three scenarios (i.e., normal, moderate and pessimistic), we simulate an increase in the public investment and in the government expenditures in 0.71% and 0.57% respectively. We consider that these amounts are directed to mitigate the risk of climate change in the agricultural sector. We obtain the following growth rates for each scenario respectively: 0.69%, 0.54% and 0.03 % (see Figure 5).

Figure 4: The Real GDP Growth Rate Scenarios without Mitigation 2007 - 2017



Source: Own elaboration on basis of MEGC.

Figure 5: Real GDP Growth Rate Without Mitigation 2007 - 2017



Source: Own elaboration on basis of MEGC.

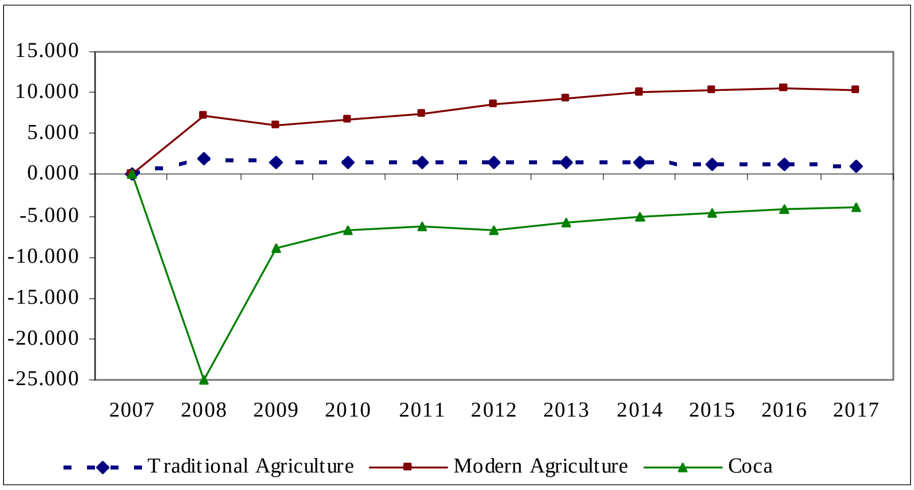
The results show that the resources destined to mitigate the adverse effects in the pessimistic scenario permit to maintain positive growth rates. This supports the theory that negative climate effects produced strong falls in economic growth, specially in the agricultural sector. The mitigation does not eliminate the effect, but it reduces it in the short run.

6.2. The Normal Scenario (without Mitigation)

In this section we analyse the performance of the three most representative activities of the agricultural sector (i.e., traditional agriculture, modern agriculture and coca) without mitigation. The results show that the traditional agricultural sector has a cointegrated behaviour with the modern agriculture sector. This means that their dynamics move together, although modern agriculture shows an average growth rate of 7.84% throughout the next 10 years forecast and the traditional sector shows a flat growth (see Figure 6). Finally, the coca sector is the most affected by climate change; however, this happens because the model was calibrated with data of 2004, when the level of coca production was inferior to the current one, therefore, any decrease affects more.

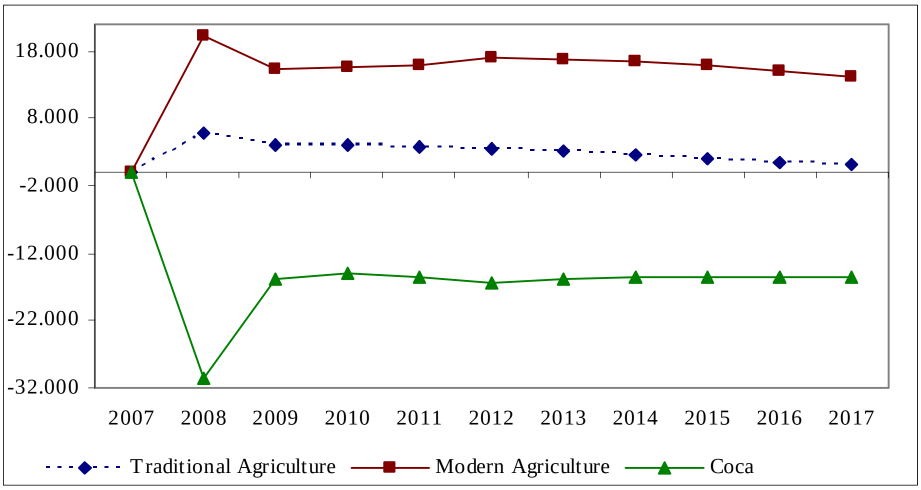
Regarding to the export behaviour, the growth rate is 0.71% without mitigation and 0.75% with mitigation, therefore, both trajectories are overlapped and there is no major effect of mitigation over the export performance. We disaggregate export by activities; in the Figure 7 we observe that the key incidence on agriculture occurs in the non-traditional export products, mainly soy.

Figure 6: Percentage of Real Domestic Growth Rate 2007 - 2017



Source: Own elaboration on basis of MEGC.

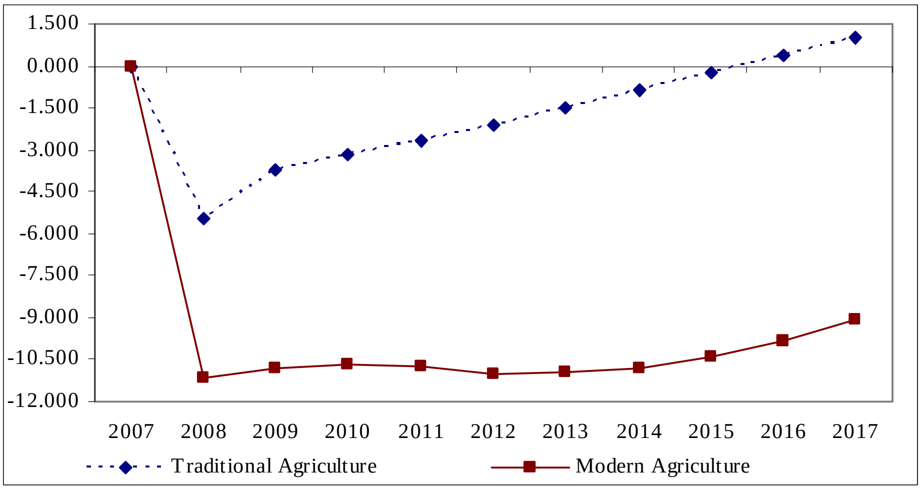
Figure 7: Percentage of Real Exports Growth Rate 2007 - 2017



Source: Own elaboration on basis of MEGC.

The average growth rate of Bolivian agricultural imports falls 3.75%. As we can see in Figure 8, the most important reduction is given in the modern agriculture, because a smaller agricultural production demands less import inputs (e.g. fertilizers). On the other hand, food requirements are associated more with traditional agriculture; therefore the imports diminish only in the very short term.

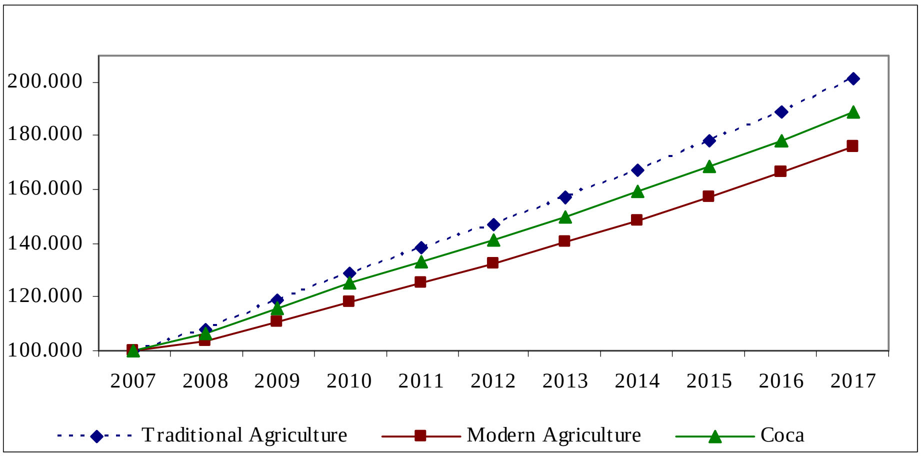
Figure 8: Percentage of Real Imports Growth Rate 2007 - 2017



Source: Own elaboration on basis of MEGC

Even in the absence of negative effects in the agricultural sector (with or without mitigation measures), due to the scarcity of products all domestic prices (i.e. traditional, modern and coca) tend to rise (see Figure 9). At the same time, since higher prices reduce consumption and given the high degree of labor intensity, the agricultural wages are reduced.

Figure 9: Price Index of Domestic Product 2007 - 2017

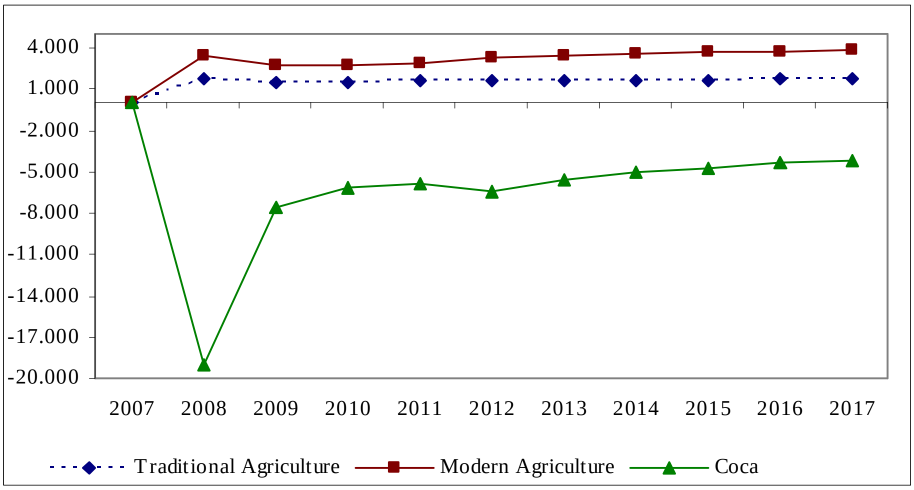


Source: Own elaboration on basis of MEGC.

6.3. The Moderate Scenario (with Mitigation)

In this scenario we expect the occurrence of some climatic phenomena, but not the high intense "Mega Niños". With this experiment we seek to evaluate the impact of mitigation measures destined to diminish the risk and vulnerability in the agricultural sector. We conclude that the domestic production shows the same growth rate of 2.25%, both in the traditional and modern activities. This means that mitigation measures have almost no impact when the climatic phenomenon is not extreme. Also, coca production drops 6.2%, because this is clearly not an agro-alimentary sector (see Figure 10).

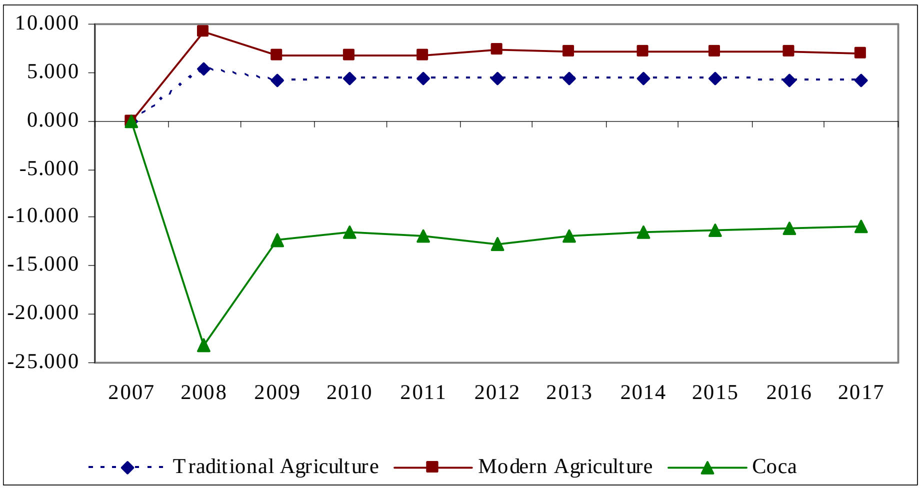
Figure 10: Real Domestic Product Growth Rate 2007 - 2017



Source: Own elaboration on basis of MEGC.

The mitigation expenditure defined as "public investment" for climate change risk reduction, has a *crowding-in effect,* since it increases the exports from -0.39% to -0.34%. At the same time the real exchange rate depreciates, specially in favour of modern agricultural products (see Figure 11).

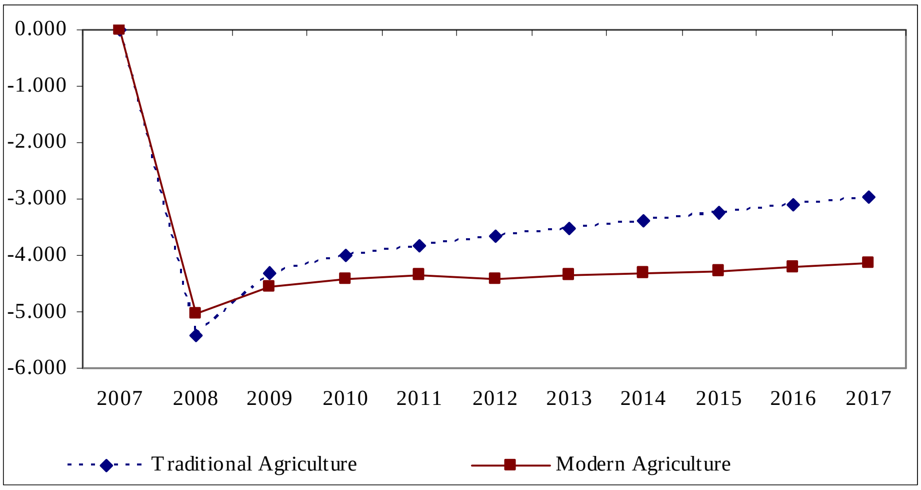
Figure 11: Percentage of Real Exports Growth Rate 2007 – 2017



Source: Own elaboration on basis of MEGC.

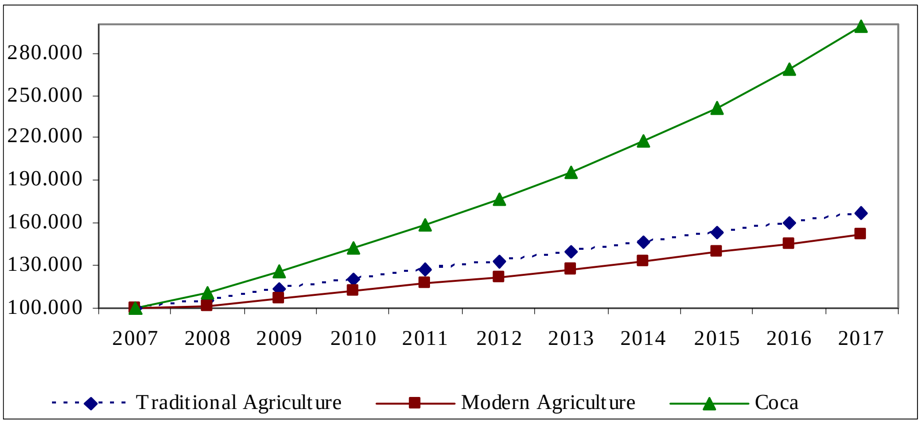
The growth rate of imports drops -2.4%, with an important reduction in relation to the normal scenario. The imports in the traditional agricultural sector react quickly; because they are more associated with food requirements. The government moreover increases its expenditures toward food imports, specially when traditional agriculture falls lower than modern agriculture (see Figure 12).

Figure 12: Percentage of Real Imports Growth Rate 2007 - 2017



Source: Own elaboration on basis of MEGC.

Figure 13: Price Index of Domestic Product 2007 - 2017



Source: Own elaboration on basis of MEGC.

An increase in the government expenditure destined to mitigate the effect of climate change, on the one hand stabilises agricultural production – on the other hand, it elevates symmetrically the price level (see Figure 13) in both activities (i.e. traditional and modern) (see Figure 13). The net effect in the global consumption price Index (CPI) is no matter of this research.

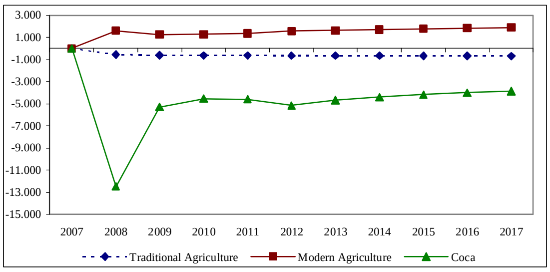
6.4. The Pessimistic Scenario

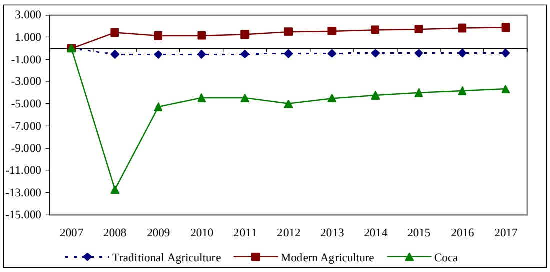
The agricultural production depends mainly on environmental conditions like soil quality, temperature, altitude, etc. Unfortunately, this information is expensive and also difficult to introduce into an economic model. Since the CGE model used for this research was designed for macroeconomic and aggregate sectoral analysis, it does not capture the full long term climatic dynamic.

When we simulate an extreme shock over the agricultural production due to climate change (pessimistic scenario) we are looking for a long term evaluation related to specific activities (i.e. traditional, modern and coca). In this experiment we assume both possibilities (i.e. with and without mitigation). The results are the expected ones, the exercise shows negative growth rates of -1.32% and -1.2% respectively (see Figure 14).

Figure 14: Percentage of Real Domestic Product Growth Rate 2007 – 2017

With Mitigation **Without Mitigation**



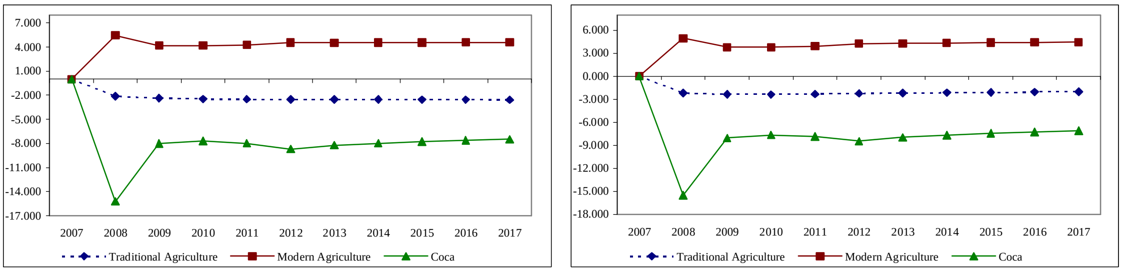


Source: Own elaboration on basis of MEGC.

The exports diminish (see Figure 15) except in modern agriculture. The behaviour of all activities is the expected one and the trajectories are very similar with and without mitigation, with an average growth rate of -2% and -1.8% respectively. The conclusion is that extreme phenomena overshoot the agricultural production function, thus mitigation expenses do not have a major impact. When successive extreme phenomena occur, the possibility of production shortage in all agricultural areas increases. Therefore, there is a drop in exports with an exchange rate appreciation, mainly in the modern agricultural sector.

Figure 15: Percentage of Real Exports Growth Rate 2007 – 2017

With Mitigation **Without Mitigation**

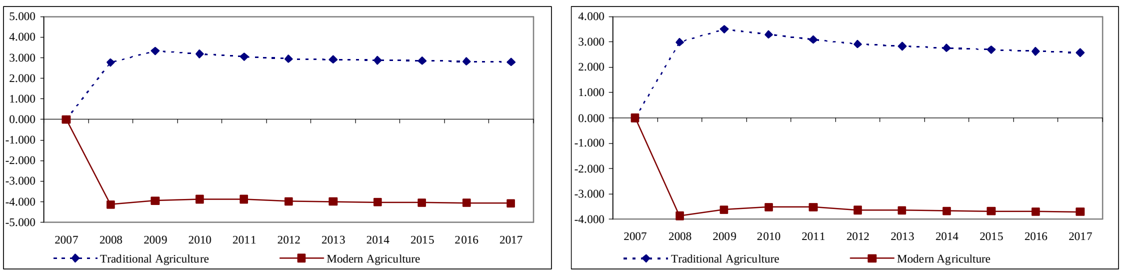


Source: Own elaboration on basis of MEGC.

Given the budget constraints, the derived effects from climate change push up the imports of traditional agricultural goods (specially food) and lower the imports of modern agricultural goods. We observe the effect mainly in the mid term (see Figure 16). It is evident that there is a very slow technological change in the modern agriculture sector and subsistence production in the traditional agriculture sector.

Figure 16: Percentage of Real Imports Growth Rate 2007 – 2017

With Mitigation **Without Mitigation**

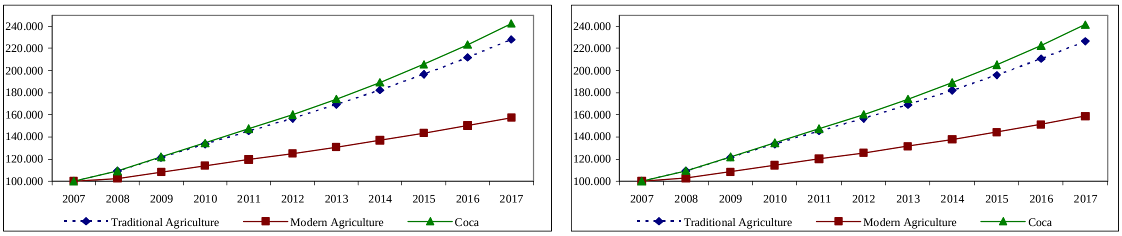


Source: Own elaboration on basis of MEGC.

As a result of extreme or chronic climate change, the price index doubles in relation to the normal scenario. There is a structural broke in the production function in the long term which shows the powerlessness of mitigation measures when these type of events occurs. Thus the demand grows and the production decreases until the nature internalises that event (see
Figure 17).

Figure 17: Index Prices of Domestic Product 2007 – 2017

With Mitigation **Without Mitigation**



Source: Own elaboration on basis of MEGC.

7. Conclusion and recommendations

Agriculture is the most vulnerable activity to extreme climate change. The impact on economic growth is significant, specially in the short and mid term (when production decreases and prices increase). In the case of extreme and chronic climate events the economic effects are not clear, because there is a very slow environmental internalisation of this type of phenomena.

We conclude that there is strong evidence that climate change leaves sequels in the agricultural production function in the mid term. In all the scenarios climate change affected the trade balance and the terms of trade, with major incidence over the prices in the traditional agriculture in the short term.

With more mitigation expenditures destined to reduce risk and vulnerability to climate change, the effects diminish, but in most of the cases marginally. The main conclusion is that mitigation in the best case stabilises the adverse effects of climate change, but it is not enough to substitute the planned adaptation.

It is not possible to extract additional information from previous studies. Therefore it is recommended that new research will be undertaken.

- A complete vulnerability analysis should be done for the agricultural sector regarding to the effect of climate change on agriculture and the second round effects on the other sectors of the economy.
- It is necessary to build an integrated CGE model with climate change and agricultural models in order to take the dynamic nature of things into account.
- Further research is needed to examine the role of climate change variables in land management adaptations.

Finally, we addressed the following questions, because Bolivia does not have a complete climate change model that allows us to analyse the overall mitigation and adaptation measures.

- What are the attributes of climate to which agricultural systems respond?
- Where and when mitigation is necessary?
- What type of mitigation do we need?
- Why do responses differ, and what characteristics make certain types of regions more vulnerable or adaptive than others?

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