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Carbon Tax Effect on the Cereals Market and Electricity Sector in Morocco

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Abstract: ***In the two last decades, many countries mainly in Europe have adopted policies to reduce carbon emissions, and one of the most effective and popular of these policies is the carbon tax. We simulate the effects of this policy on the Moroccan economy to see its effects mainly on GDP and carbon emissions. We used for this purpose a partial equilibrium model that modelize the market of cereals along with the sector of electricity, with five scenarios from 0,5 to 2,5 USD/ton CO2. The results show that a rate of only 0,5 USD/ton CO2 can significantly reduce carbon emissions while reducing very lightly the GDP, so we encourage the use of the carbon tax at that rate.***

Keywords: Partial equilibrium model, carbon tax, emissions, cereals market, electricity sector

1. Introduction

In this article we look at the problem that greenhouse gas pollution, especially carbon, causes to the environment, and the appropriate ways to counteract these effects. Indeed, there are various environmental policies to deal with this problem, and one of the most common and well - known is carbon taxation.

This policy has been advocated and widely implemented in a number of countries for several decades now, and several research papers have analyzed its impact, mainly on emissions and gross domestic product, with the aim of assessing its effectiveness in significantly reducing carbon emissions without being a brake on economic growth. The results of most of these papers show that the carbon tax is a rather effective policy.

For our part, we are interested in the case of Morocco, which has not yet put in place an environmental policy as such, apart from its growing investment in renewable energy, and more particularly in the key sector of the Moroccan economy, namely agriculture.

We propose to test the carbon tax policy on the agricultural sector, in particular the cereal market which is dominated by wheat and barley, with a partial equilibrium model in order to see the effect of different carbon tax prices on emissions, income, as well as the consumption and production of the three products of interest to us, i. e. electricity, wheat and barley, as well as the intermediate consumptions of natural gas, coal and diesel which are used as inputs to produce electricity and cereals respectively.

After the introduction, we will see a literature review adapted to our problematic, we will present the model and the data sources, then the numerical analysis with our partial equilibrium model and the ensuing results, before ending with a general conclusion.

2. Literature Review

The carbon tax is a state - imposed tax that takes two forms: either companies pay a price for their CO2 pollution, or consumers pay a higher price on polluting products such as hydrocarbons. This policy is seen as effective in reducing carbon emissions by most authors who have dealt with the subject. We will present summaries of their work in the following.

Metcalf (2018) says that interest in a hybrid carbon tax that provides some assurance that emission reduction targets will be met has emerged recently. To better understand how such a hybrid tax might work, he describes a prototype emissions assurance mechanism (EAM) that would provide practical policy certainty that is easy to understand and simple to implement. It outlines an EAM that would reduce energy - related carbon dioxide emissions by 45% by 2035 compared to 2005 emissions. In 2035, an assessment would be made of an emissions reduction target for the next 15 years.

Emissions are compared to an emissions trajectory for each year. As long as cumulative emissions since the first year of the carbon tax do not exceed cumulative emissions along the emissions trajectory, the carbon tax rate would increase by a standard indexation factor of 5% per year (plus inflation). If cumulative emissions exceed cumulative emissions along the trajectory, an accelerated indexation factor of 10% would be implemented to increase the tax rate each year. Similarly, if cumulative emissions fall well below the pathway, the tax rate would be held constant (in real terms). The emissions pathway and EAM would be incorporated into the carbon tax legislation.

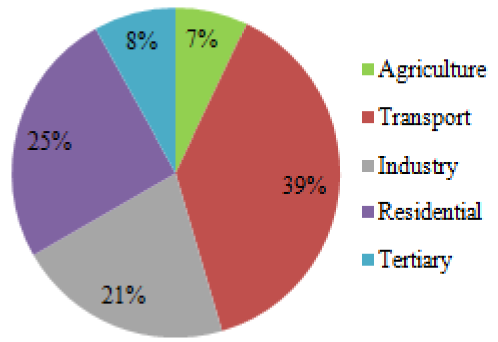
A carbon tax is a simple, transparent, market - based instrument that can provide an effective incentive for the US economy to reduce carbon emissions. An Environmental Assurance Mechanism (EAM) modelled on10 EIA initially publishes annual data in the March Monthly Energy Review (published towards the end of the month). The April edition may revise the data slightly. This gives the Treasury Department time to draft and publish a notice of the following year's tax rate before 1 June. The EIA periodically revises its energy - related carbon dioxide data series based on new information. Since the tax rate would be based on cumulative emissions, the Energy and Treasury Departments would need to develop guidance on the measurement of historical emissions that would be used to set future tax rates. It is unlikely that whether the rule uses preliminary or final estimates of emissions and whether revisions to the historical emissions series are allowed would have a significant impact on tax rate setting.

However, clear guidelines should be developed so that everyone understands how the process works. One example is the marginal sink tax credit, which is allowed when prices fall below a threshold price (26 U. S. C. § 45I [2007]). The one described in this paper would add good assurances that an ambitious but politically and technologically challenging 45% emissions reduction target by 2035 would be achieved; a one - off reassessment at that time could set a new emissions reduction target through 2050. Alternatively, a longer - term target to 2050 could also be set in the original legislation, although given the greater uncertainties in projecting technological innovations and costs in the coming years, a shorter - term target with a one - off assessment might be a better approach.

Liu et al (2018) develop a computable general equilibrium (CGE) model for the province of Saskatchewan is first developed to examine and analyse a range of both direct and indirect socio - economic impacts of a carbon tax. The energy sector is then disaggregated by production structure and energy use pattern to obtain robust results. Different carbon tax rates are simulated to quantify the interrelationships between the carbon tax, economic growth and GHG emission reductions. In - depth examinations are also carried out to investigate some other macroeconomic impacts and the responses of specific economic sectors.

The results show that the change in GDP is mainly caused by reduced consumption and increased imports, due to lower incomes and relatively low tariff rates. Changes in the production and processing of coal and petroleum products cause the highest GHG emissions of all sectors. This means that clean coal and oil technologies could be the critical issues for achieving provincial and national environmental and economic goals. The authors expect that the results will provide a solid foundation to support the implementation of an effective Canada - wide carbon pricing strategy.

Figure 1: Electricity consumption by sector in Morocco



Source: Prepared by us based on data from the Heinrich Böll Foundation Rabat – Morocco

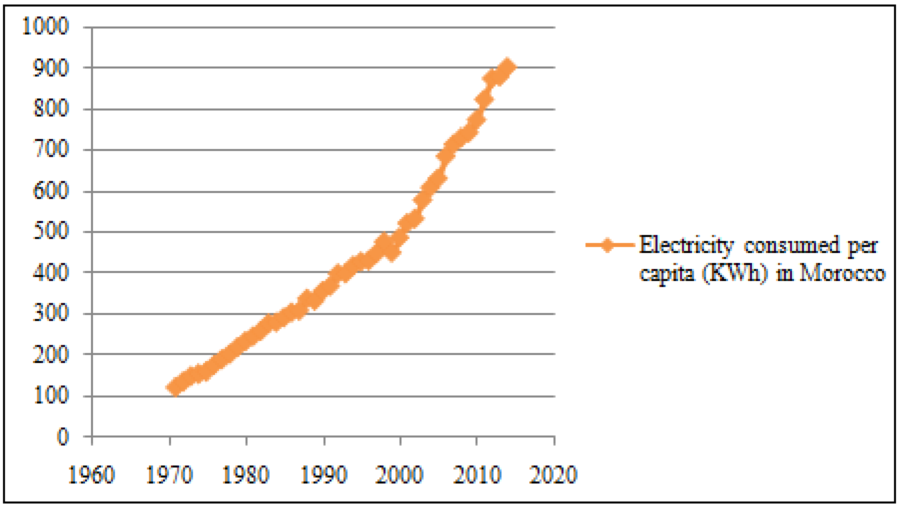


Figure 2: Electricity consumed per capita (KWh) in Morocco
Source: Prepared by us based on World Bank data

It has been found that a carbon tax would reduce greenhouse gas emissions while contracting the economy. A further increase in the carbon tax rate will result in sharp declines in GDP. This suggests that in a resource - intensive economy such as Saskatchewan's, where there is little opportunity for fuel switching, a carbon tax will simply lead to decisions to contract economic activity, rather than adapt to it. Coal and petroleum products make the largest contribution to the decline in combustion - related GHG emissions, indicating that clean coal and petroleum technologies may be the critical issues in achieving simultaneous economic growth and GHG reductions.

Zhang and Zhang. (2018) using a computable general equilibrium model, present a simulation study of the changes in carbon emissions and economic welfare that could be caused by a carbon tax policy in the tourism industry in China. Their results clearly show that a carbon tax policy could have a significant impact on tourism - related carbon emissions and economic welfare. Moreover, they find that these impacts would differ significantly across time. Furthermore, the effects of different carbon taxes on different sectors of the tourism industry are also very different.

They use CGE modelling and perform a full simulation analysis of the impacts of a carbon tax on the Chinese tourism industry. The model uses different carbon tax rates of ¥10/t - CO2, ¥50/t - CO2 and ¥90/t - CO2. The simulation results indicate that a carbon tax can effectively reduce tourism - related CO2 emissions, especially those related to the carbon intensity of tourism. The implementation of a carbon tax policy can significantly promote the reduction of tourism - related CO2 emissions in China. The levy of a carbon tax would result in significant economic costs for the Chinese tourism industry due to the reduced contribution of tourism to the national economy and the reduction of employment in the tourism sector. In general, a higher carbon tax has a greater impact on tourism CO2 emissions and the economy, while these impacts decrease over time. In other words, the impacts of a tax on tourism are greater in the short term than in the long term. Furthermore, the impacts of a carbon tax vary considerably between tourism sectors.

Dong (2017) notes that with rapid development, it is not easy for China to achieve carbon reduction targets only through traditional command and control measures (e. g. energy efficiency measures). Carbon tax is recommended as an effective complementary measure and has a high chance of being implemented for China's future low - carbon development. Under these circumstances, he aims to predict the possible impact of carbon tax on the carbon emission reduction and economic loss of 30 Chinese provinces. A computable general equilibrium model of 30 Chinese provinces is developed to carry out the provincial assessment, and seven scenarios including business - as - usual (BaU) scenario and six carbon tax scenarios with a carbon price of USD 20/ton to USD 120/ton until 2030 are developed.

The results show that China's industrial CO2 will be reduced from 12.2 billion tonnes under the BaU scenario to 10.4 billion tonnes, 9.3 billion tonnes, 8.5 billion tonnes, 7.9 billion tonnes, 7.4 billion tonnes and 7 billion tonnes under the TAX20, TAX40, TAX60, TAX80, TAX100 and TAX120 scenarios in 2030, respectively. The electricity, metals and chemicals sectors have a high reduction potential and are priority sectors for carbon taxation policy. The analysis of provincial disparities reveals that coal production/consumption and total energy consumption are key factors in influencing the effect of the carbon tax on CO2 reduction, and Inner Mongolia, Shandong, Shanxi and Hebei have the highest industrial CO2 reduction potentials after levying the carbon tax.

However, the implementation of the carbon tax will hamper the economic development of all provinces. Hence, the concept of carbon tax efficiency is proposed to assess the effectiveness of the carbon tax by considering both CO2 reduction and GDP decrease. Policy suggestions indicate that Shanxi, Inner Mongolia, Hebei and Anhui provinces should be prioritised in the implementation of carbon tax policy in China, and that the carbon price should not exceed USD 50/tonne.

Li and Jia (2016) use a dynamic recursive computable general equilibrium (CGE) model to analyse the economic, energy and environmental impact of CO2 emission reduction policy based on 17 scenarios in China: carbon tax, emission trading scheme and mixed policy, to determine which type of emission reduction strategy is better. The results indicate that CO2 emissions in 2030 will be reduced by implementing the tax, the ETS and the mixed policy, by 10 - 13%, 12 - 14% and 18 - 28%, respectively. From 2016 to 2030, China can reduce 18, 338 to 24, 156 Mt of CO2 through the use of a mixed policy.

Although most authors have found that carbon tax policy is effective in significantly reducing CO2 emissions without harming economic growth, this position is not unanimous, there are indeed papers that say that carbon tax is not an effective policy for lowering carbon emissions, and we will present summaries of this work in what follows.

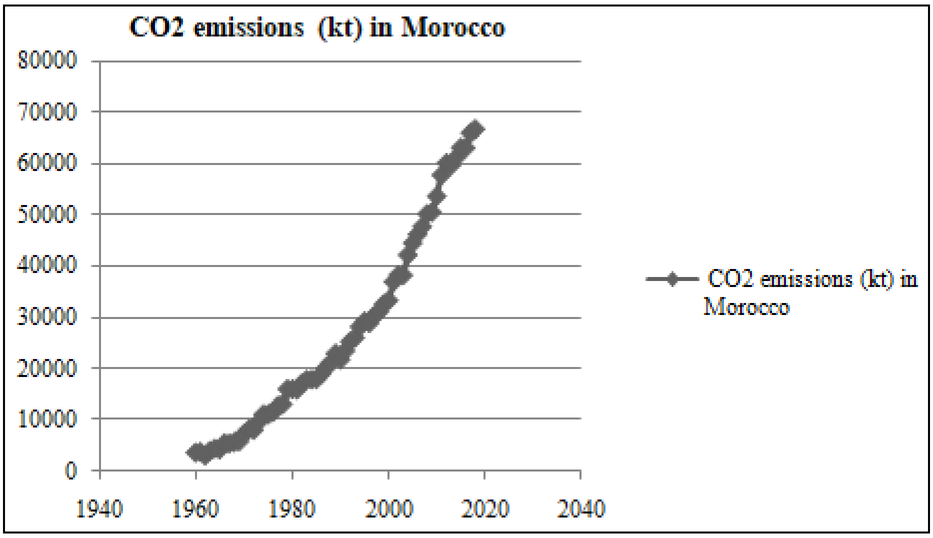
Kuo et al (2016) examine the interactions between a government and a firm in implementing carbon taxes over time or by tax level, taking into account greenhouse gas emissions. They examine the impact of different carbon tax policies on business investment in new technologies, on the reduction of the amount of production and on tax transfers from governments. A case study of the strategic responses of three companies in Taiwan's electronics, cement and steel industries to two government carbon reduction policies shows that appropriate levels of taxation can induce a company to change its production processes to reduce emissions as part of a long - term business strategy.

As expected, in the situation of low carbon tax and high expenditure on improving production processes or replacing old production equipment, regardless of the scenarios adopted by the government, companies do not choose to reduce their carbon emissions, due to the likelihood of high investment costs and relatively low carbon taxes. Given the low expenditure on improving production processes or replacing old production equipment, this case study still shows that a company will not reduce its carbon emissions even if the government levies a low tax. The authors therefore conclude that policymakers may need to provide other incentives to offset the costs of improving production processes, or impose a substantial tax penalty if the company decides not to reduce its carbon emissions.

Vera and Sauma (2015) find that many countries have not yet succeeded in decoupling their growth and energy consumption. In addition, electricity generation often entails a number of negative externalities, such as greenhouse gas emissions from thermoelectric units. This situation has highlighted the need for countries to move towards sustainable economic development. As a result, many countries have proposed and implemented measures to reduce their CO2 emissions. In this sense, the Chilean government has adopted a carbon tax of $5/tonne of CO2. They compare the effects of this tax on the reduction of CO2 emissions with certain energy efficiency measures in the electricity sector.

The results show that the imposed carbon tax will produce an annual decrease in CO2 emissions of 1% compared to the estimated baseline over the period 2014 - 2024. Nevertheless, this decrease will be accompanied by an expected increase of 3.4% in the marginal cost of electricity generation in the main Chilean electricity system. On the other hand, the introduction of some energy efficiency measures, aiming at reducing the electricity demand of the residential sector by 2%, could further reduce CO2 emissions, while at the same time reducing the price of energy.

On the other hand, they show that the introduction of certain energy efficiency measures, decreasing electricity demand in the residential sector by 2%, could reduce CO2 emissions more strongly than this carbon tax while simultaneously decreasing the price of electricity. Furthermore, when a $5/tonne CO2 tax is introduced and a 2% decrease in expected demand is considered together, the reduction in CO2 emissions is smaller than when considering a 3% decrease in expected demand (without a carbon tax).



Source: Prepared by us based on World Bank data

Lin and Li (2011) state that as the most effective market - based mitigation instrument, the carbon tax is strongly recommended by economists and international organisations. Countries such as Denmark, Finland, Sweden, the Netherlands and Norway have been early adopters of the carbon tax and as such, research on the impacts and problems of implementing the carbon tax in these countries will be of great practical importance and will encourage countries that are to levy the tax to exercise caution. In contrast to existing studies that adopt model simulation approaches, the authors have comprehensively estimated the actual mitigation effects of the five northern European countries using the difference - in - differences (DID) method.

The results show that the carbon tax in Finland has a significant and negative impact on the growth of its CO2 emissions per capita. However, the impacts of the carbon tax in Denmark, Sweden and the Netherlands are negative but not significant. The mitigating effects of the carbon tax are weakened due to tax exemption policies for some energy intensive industries in these countries. However, in Norway, as the rapid growth of energy products leads to a substantial increase in CO2 emissions in the oil drilling and natural gas exploitation sectors, the carbon tax has not actually achieved its mitigation effects.

Furthermore, GDP per capita is positively correlated with the growth rate of CO2 emissions per capita and the structure of industry (tertiary industry). R&D expenditure, as well as the price of energy, have a negative and significant influence on CO2 emissions per capita. Furthermore, the impact of urbanisation on CO2 emissions per capita is insignificant, probably because most countries have almost completed the urbanisation process (the urbanisation rate is above 60%). Finally, the effectiveness of the carbon tax differs from country to country, with the carbon tax in Finland having a negative and significant impact on CO2 emissions. The efficiency of the intermediate target is 0.0169, which means that the implementation of the carbon tax decreased the growth of CO2 emissions per capita in Finland by 1.69% compared to what it would have been without the tax. On the other hand, the coefficients of the interaction terms for Denmark, Sweden and the Netherlands are also negative, but the significance test was not exceeded, indicating that the effects of the carbon tax in these countries are limited. As this coefficient does not pass the significance test, it proves that the carbon tax in Norway has little impact on CO2 mitigation.

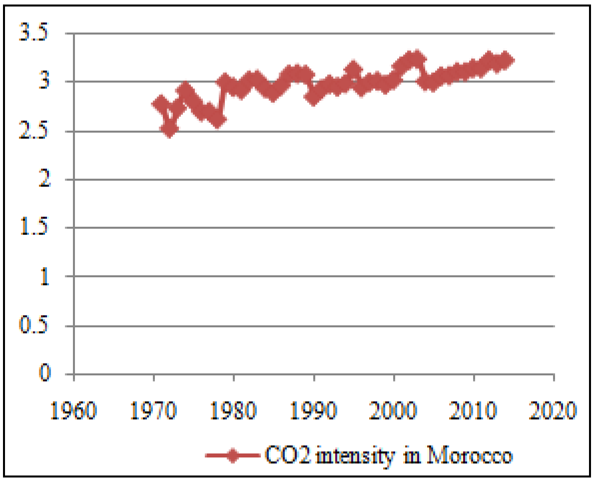


Figure 4: CO2 intensity in Morocco from 1971 to 2014
Source: Prepared by us based on World Bank data.

Tol (2007) uses a simulation model of international tourism flows to estimate the impact of a carbon tax on aviation fuel. The effect of the tax on traveller behaviour is small: a global amount of \$1000/t would change traveller behaviour to reduce carbon dioxide emissions from international aviation by 0.8%. This is because the tax imposed is likely to be small in relation to the price of air travel. A tax of \$1, 000/t would be less than double the airfare and have less impact on the total cost of a holiday.

In addition, price elasticity is low. A carbon tax on aviation fuel would particularly affect long - haul flights, due to high emissions, and short - haul flights, due to emissions at take - off and landing. Medium - haul flights would be the least affected. This means that tourist destinations that rely heavily on short - haul flights (i. e. islands close to continents, such as Ireland) or intercontinental flights (e. g. Africa) will see their international tourist numbers fall, while other destinations may see their international arrivals increase. If the tax is only applied to the European Union, EU tourists would stay closer to home, so that European tourism would grow at the expense of other destinations. Sensitivity analyses show that the qualitative evidence is strong. A carbon tax on aviation fuel would have little effect on international tourism, and little effect on emissions.

He suggests that the paraffin tax would induce a shift from long - haul to medium - haul flights, a shift from medium - haul flights to short - haul holidays by car and train, and a shift from short - haul flights to medium - haul flights. Island countries would be disproportionately affected by a paraffin tax. If the tax is applied regionally rather than globally, the taxed region loses market share to the untaxed region. Emissions would fall only slightly, even if the paraffin tax were very high, because a paraffin tax would increase the cost of flying only to a limited extent. In other words, very high paraffin taxes would be needed to significantly reduce carbon dioxide emissions from international aviation. The emissions reduction can be achieved elsewhere for much less money.

Conefrey et al (2013) analyse the medium - term effects of a carbon tax on growth and CO2 emissions in Ireland, a small open economy. They find that there is a double dividend if the revenue from the carbon tax is recycled through a reduction in income tax. If the revenue is recycled by giving a lump sum transfer to households, a double dividend is unlikely. They also find that the carbon tax hits capital more than labour and that when combined with an income tax cut, the tax burden clearly shifts from labour to capital. Ultimately, the majority of the effects on the economy are due to changes in the competitiveness of the manufacturing and market services sectors. These results hold even if changes in energy prices are allowed to have an increased (negative) effect on Ireland's competitiveness.

A double dividend in Ireland is possible if carbon tax revenues are recycled through a reduction in income tax. This shifts the tax burden from labor to capital. In a small open economy like Ireland, where labor is particularly mobile and labor costs are an important component of international competitiveness, this tends to improve economic performance. No double dividend is likely to occur if income is returned to households as a lump sum payment. They find that the main channel through which tax changes affect the economy is in fact changes in the international competitiveness of the manufacturing and service sectors. If the Irish economy is allowed to evolve according to recent forecasts, the effect of a carbon tax is likely to be even more favorable to the economy, while the results on carbon dioxide emissions are more mitigated.

If the carbon tax is limited to Ireland, there would be very little incentive to conduct R&D and develop new technologies. However, if the carbon price is similar across the EU, a very large market, substantial R&D and development of new technologies would be possible. If the carbon price increase were global (as with the oil price) or applied across the OECD, the effect on R&D would be even greater. Whatever the effect on R&D, as indicated here, it is likely to have a limited effect on emissions in the first decade. It is only in the longer term that a major change will occur with the introduction of new technologies developed through the carbon tax.

3. Model and Data Sources

3.1 Data Sources and Methodology

To see the impact of different carbon tax rates/prices on income, emissions and the agricultural sector, in particular the cereal market in interaction with the electricity sector, we used a partial equilibrium model whose parameters were estimated from data from the Moroccan energy balances of wheat and barley, the Moroccan energy balance of 2018 as published by the United Nations, and finally the social accounting matrix of 2015 published by the Moroccan High Commission for Planning on their official website. We have considered that the returns to scale of the factors of production are constant and that the share of each factor is proportional to the production of the given product.

3.2. Model

The variables are expressed in monetary values, more precisely in US dollars to allow international comparisons, except for the area of cultivated land which is expressed in hectares. Prices are implicit in the model. Some variables are exogenous since in the short run most inputs are fixed and the tax varies independently of the other variables since it is prescribed by the government. These variables are the intermediate consumption of oil by the electricity sector, the capital and labour used in the electricity sector, the land cultivated with wheat and barley, the capital, labour and electricity used to produce wheat and barley, and finally the tax set by the government.

3.2.1. Objective function and consumption equations:

$$\text{Max } \Omega = C_w^{\alpha Cw}.C_b^{\alpha Cb}.C_e^{\alpha Ce} - t.(FE_w.C_w + FE_b.C_b + FEe.Ce \quad (1)$$

$$\text{s.c}: Y_{tot} - C_w - C_b - C_e - EL_w - EL_b = 0 \quad (2)$$

where C_w is the consumption of wheat, C_b is the consumption of barley, C_e is the consumption of electricity, Y_{tot} is the total revenue, EL_w is the intermediate consumption of electricity to produce wheat, EL_b is the

intermediate consumption of electricity to produce barley and t is the price of the carbon tax in USD/tonne CO2.
First order conditions:

$$\alpha_{Cw}.C_w^{\alpha_{Cw}-1}.C_b^{\alpha_{Cb}}.C_e^{\alpha_{Ce}} - t.FE_w - \lambda = 0 \quad (3)$$

$$\alpha_{Cb}.C_b^{\alpha_{Cb}-1}.C_w^{\alpha_{Cw}}.C_e^{\alpha_{Ce}} - t.FE_b - \lambda = 0 \quad (4)$$

$$\alpha_{Cb}.C_b^{\alpha_{Cb}-1}.C_w^{\alpha_{Cw}}.C_e^{\alpha_{Ce}} - t.FE_b - \lambda = 0 \quad (5)$$

$$C_w + C_b + C_e + EL_w + EL_b = Y_{tot} \quad (6)$$

3.2.2. Production and intermediate consumption functions:

$$Y_e = PET_e^{\alpha_{PETe}}.G_e^{\alpha_{Ge}}.CO_e^{\alpha_{COe}}.L_e^{\alpha_{Le}}.K_e^{\alpha_{Ke}} \quad (7)$$

$$Y_w = Z_w^{\alpha_{Zw}}.L_w^{\alpha_{Lw}}.K_w^{\alpha_{Kw}}.EL_w^{\alpha_{ELw}}.DI_w^{\alpha_{DIw}} \quad (8)$$

$$Y_b = Z_b^{\alpha_{Zb}}.L_b^{\alpha_{Lb}}.K_b^{\alpha_{Kb}}.EL_b^{\alpha_{ELb}}.DI_b^{\alpha_{DIb}} \quad (9)$$

Where Y_e is the production of electricity, Y_w is the production of wheat, Y_b is the production of barley, PET_e is the intermediate consumption of petroleum products to produce electricity, G_e is the intermediate consumption of natural gas to produce electricity, CO_e is the intermediate consumption of coal to produce electricity, L_w is the labour used to produce electricity, K_w is the physical capital used to produce electricity, Z_w is the area cultivated with wheat, L_w is the labor used to produce wheat, K_w is the physical capital used to produce wheat, EL_w is the intermediate consumption of electricity to produce wheat, DI_w is the diesel consumed to produce wheat, Z_b is the area cultivated with barley, L_b is the labor used to produce barley, K_b is the physical capital used to produce barley, EL_b is the intermediate consumption of electricity to produce barley and DI_b is the intermediate consumption of diesel to produce barley.

3.2.3. Equilibrium equations

$$C_w + C_b + C_e + EL_w + EL_b = Y_{tot} \quad (6)$$

$$C_e = Y_e - EL_w - EL_b \quad (10)$$

$$C_w = Y_w \quad (11)$$

$$C_b = Y_b \quad (12)$$

$$Y_{tot} = Y_e + Y_w + Y_b \quad (13)$$

3.2.4 Carbon emissions equation:

$$EM = FE_w.C_w + FE_b.C_b + FE_e.C_e \quad (14)$$

Where EM is the CO2 emissions in kg.

Table 1: List of model parameters with their calibrated values

Parameter	Meaning	Value
alphaPETe	Oil factor in electricity generation	0.1203
alphaGe	Methane factor coefficient in electricity production	0.2195
alphaCOe	Coefficient of coal factor in electricity generation	0.5222
alphaLe	Coefficient of labor input in electricity generation	0.1139
alphaKe	Capital Factor Coefficient in Electricity Generation	0.1914
alphaZw	Coefficient of land factor in wheat production	0.001316
alphaLw	Coefficient of labor input in wheat production	0.1448
alphaKw	Coefficient of capital factor in wheat production	0.2466
alphaELw	Coefficient of electricity factor in wheat production	0.03948
alphaDIw	Coefficient of diesel factor in wheat production	0.05314
alphaZb	Coefficient of land factor in barley production	0.0007071
alphaLb	Coefficient of labor input in barley production	0.07782
alphaKb	Coefficient of capital factor in barley production	0.1545
alphaELb	Coefficient of electricity factor in barley production	0.03146
alphaDIb	Coefficient of diesel factor in barley production	0.05682
alphaCw	Share of wheat consumption in total consumption	0.5815
alphaCb	Share of barley consumption in total consumption	0.2317
alphaCe	Share of electricity consumption in total consumption	0.1868
FEw	Wheat emission factor	0.1392
FEb	Barley emission factor	0.1489
FEe	Electricity emission factor	8.229
lambda	Multiplier of the Lagrangian of the objective function	0.6535

4. Numerical Analysis and Results

We used our model above to test the effectiveness of the carbon tax on the Moroccan economy, more specifically the agricultural sector and the cereals market, through five scenarios, each with a different price of the carbon tax ranging from 0.5USD/tonne of CO2, to 2.5USD/tonne of CO2 in steps of 0.5USD/tonne of CO2. We obtained the results presented in the following.

4.1 Scenario 1: 0, 5USD/ton of CO2:

The carbon tax of 0.5 USD/tonne of CO2 has resulted in a decrease in the consumption of electricity, which has become much more expensive, and therefore a decrease in its production. Electricity consumption decreased by 3.342%, and its production by the same amount. The fact that electricity has a much higher carbon emission factor than the other products in the model, namely wheat and barley, has induced a crowding out effect of income that will be spent on consuming these products rather than electricity, so that their consumption and therefore production will increase even though they are also taxed, The consumption and production of wheat will increase by 0.629%, and that of barley by 0.110%, but this increase in their production remains lower than the decrease in the production of electricity, which means that the overall production and therefore the overall income will decrease by 2.603%.

This decrease in the consumption of electricity, which far exceeds the increase in the consumption of other products, will result in a 27.398% decrease in CO2 emissions, as electricity is much more polluting than the other goods considered in the model. This decrease in electricity production is accompanied by a decrease in the intermediate consumption of electricity in natural gas and coal of 2.286% for natural gas and 5.439% for coal, that of oil remaining unchanged since it is considered as a rigid production factor in this model. Similarly, the increase in wheat and barley production is accompanied by an increase in intermediate consumption of these products in diesel, of 11.831% for wheat and 1.940% for barley, an increase insufficient to counterbalance the decrease in emissions due to the decrease in electricity consumption.

Table 2: Variation in % of the endogenous variables of the scenario 1 model

Variable	Variation in %
Ye	- 3, 342
Ge	- 2, 286
Yw	0, 629
Diw	11, 831
Yb	0, 110
Dib	1, 940
Ce	- 3, 342
Cw	0, 629
Cb	0, 110
EM	- 27, 398
Coe	- 5, 439
Ytot	- 2, 603

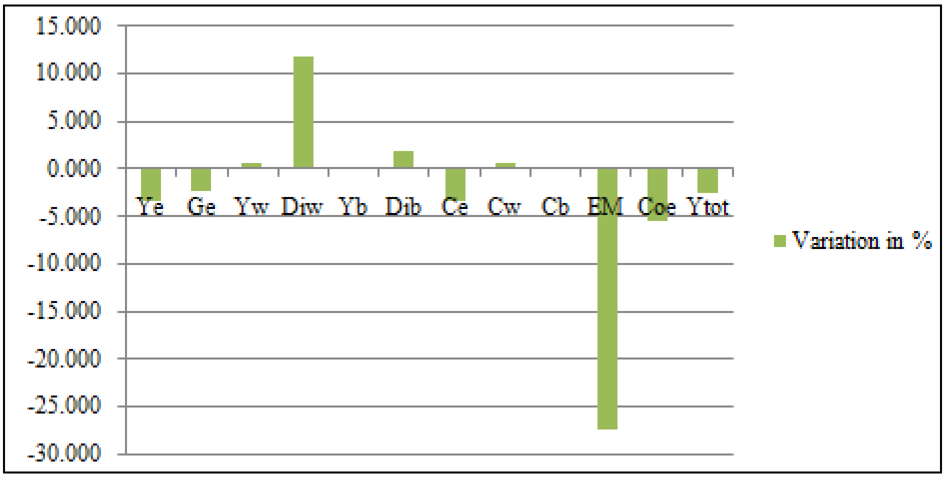


Figure 5: % change in endogenous variables following the 0.5USD/ton CO2 tax
Source: Prepared by us

4.2 Scenario 2: 1, 0 USD/ton CO2

The carbon tax of 1.0 USD/tonne of CO2 has resulted in a decrease in the consumption of electricity, which has become much more expensive, and therefore a decrease in its production. Electricity consumption decreased by 6.684%, and its production by the same amount. The fact that electricity has a much higher carbon emission factor than the other commodities in the model, wheat and barley, has caused a crowding out of income that will be spent on consuming these commodities rather than electricity, so that their consumption and therefore production will increase even though they too are taxed, The consumption and production of wheat will increase by 1.257%, and barley by 0.220%, but this increase in their production is less than the decrease in the production of electricity, which means that the overall production and therefore the overall income will decrease by 5.206%.

This decrease in electricity consumption, which far exceeds the increase in the consumption of other products, will result in a 54.796% decrease in CO2 emissions, as electricity is much more polluting than the other goods considered in the model. This decrease in electricity production is accompanied by a decrease in the intermediate consumption of electricity in natural gas and coal of 4.572% for natural gas and 10.878% for coal, that of oil remaining unchanged since it is considered as a rigid production factor in this model. Similarly, the increase in wheat and barley production is accompanied by an increase in intermediate consumption of these products in diesel, of 23.662% for wheat and 3.880% for barley, an increase insufficient to counterbalance the decrease in emissions due to the decrease in electricity consumption.

Table 4: Variation in % of the endogenous variables of the scenario 2 model

Variable	Variation in %
Ye	- 6, 684
Ge	- 4, 572
Yw	1, 257
Diw	23, 662
Yb	0, 220
Dib	3, 880
Ce	- 6, 684
Cw	1, 257
Cb	0, 220
EM	- 54, 796
Coe	- 10, 878
Ytot	- 5, 206

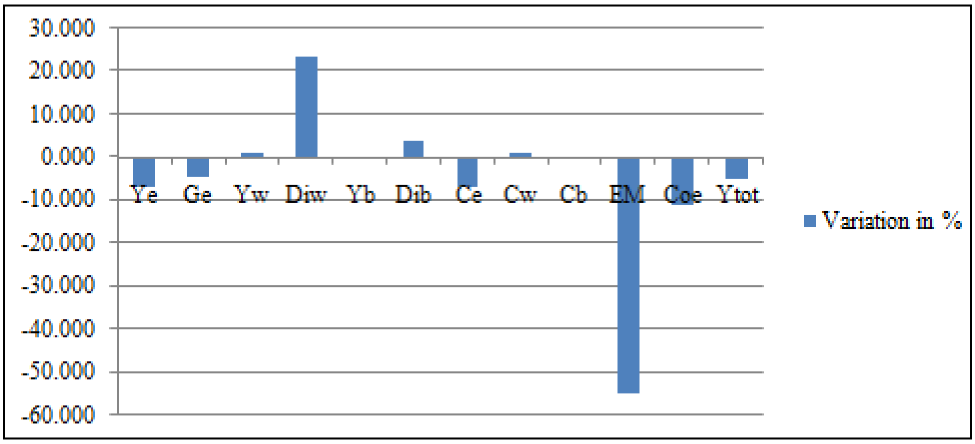


Figure 6: Variation in % of endogenous variables following the 1USD/tonne CO2 tax
Source: Prepared by us.

4.3. Scenario 3: 1, 5 USD/ton of CO2

The carbon tax of 1.5 USD/tonne of CO2 has resulted in a decrease in the consumption of electricity, which has become much more expensive, and therefore a decrease in its production. Electricity consumption decreased by 10.026%, and its production by the same amount. The fact that electricity has a much higher carbon emission factor than the other products in the model, namely wheat and barley, has induced a crowding out effect of income that will be spent on consuming these products rather than electricity, so that their consumption and therefore production will increase even though they are also taxed, The consumption and production of wheat will increase by 1.886%, and that of barley by 0.331%, but this increase in their production remains lower than the decrease in the production of electricity, which means that overall production and therefore overall income will decrease by 7.809%.

This decrease in the consumption of electricity, which far exceeds the increase in the consumption of other products, will cause CO2 emissions to decrease by 82.194%, as electricity is much more polluting than the other goods considered in the model. This decrease in electricity production is accompanied by a decrease in the intermediate consumption of electricity in natural gas and coal of 6.859% for natural gas and 16.317% for coal, that of oil remaining unchanged since it is considered as a rigid production factor in this model. Similarly, the increase in wheat and barley production is accompanied by an increase in intermediate consumption of these products in diesel, of 35.494% for wheat and 5.820% for barley, an increase insufficient to counterbalance the decrease in emissions due to the decrease in electricity consumption.

Table 4: Variation in % of endogenous variables in the scenario 3 model

Variable	Variation in %
Ye	- 10, 026
Ge	- 6, 859
Yw	1, 886
Diw	35, 494
Yb	0, 331
Dib	5, 820
Ce	- 10, 026
Cw	1, 886
Cb	0, 331
EM	- 82, 194
Coe	- 16, 317
Ytot	- 7, 809

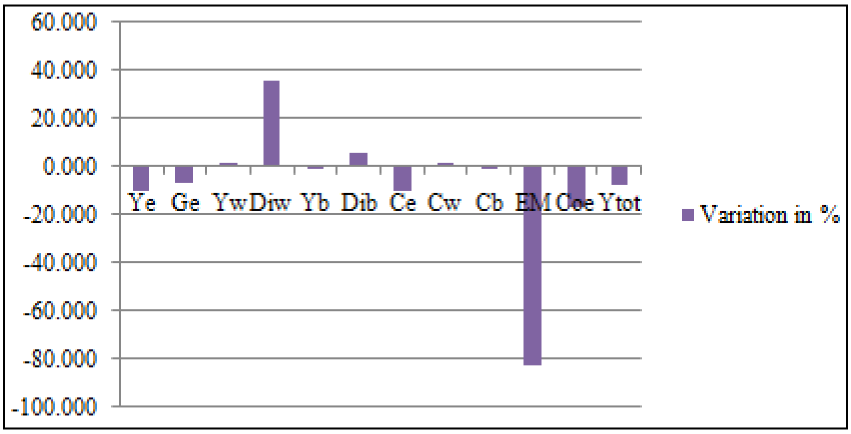


Figure 7: % change in endogenous variables following the 1.5USD/tonne CO2 tax
Source: Prepared by us

4.4. Scenario 4: 2, 0 USD/ton of CO2:

The carbon tax of 2.0 USD/tonne of CO2 has resulted in a decrease in the consumption of electricity, which has become much more expensive, and therefore a decrease in its production. Electricity consumption decreased by 13.368%, and its production by the same amount. The fact that electricity has a much higher carbon emission factor than the other products in the model, namely wheat and barley, has caused a crowding out of income that will be spent on consuming these products rather than electricity, so that their consumption and therefore production will increase even though they too are taxed, The consumption and production of wheat will increase by 2.515%, and barley by 0.441%, but this increase in production is less than the decrease in the production of electricity, which means that the overall production and therefore the overall income will decrease by 10.413%. This decrease in the consumption of electricity, which far exceeds the increase in the consumption of other products, will cause CO2 emissions to decrease by 109.590%, as electricity is much more polluting than the other goods considered in the model. This decrease in electricity production is accompanied by a decrease in the intermediate consumption of electricity in natural gas and coal of 9.145% for natural gas and 21.756% for coal, that of oil remaining unchanged since it is considered as a rigid production factor in this model. Similarly, the increase in wheat and barley production is accompanied by an increase in intermediate consumption of these products in diesel, of 47.325% for wheat and 7.760% for barley, an increase insufficient to counterbalance the decrease in emissions due to the decrease in electricity consumption.

Table 5: Variation in % of the endogenous variables of the scenario 4 model

Variable	Variation in %
Ye	- 13, 368
Ge	- 9, 145
Yw	2, 515
Diw	47, 325
Yb	0, 441
Dib	7, 760
Ce	- 13, 368
Cw	2, 515
Cb	0, 441
EM	- 109, 590
Coe	- 21, 756
Ytot	- 10, 413

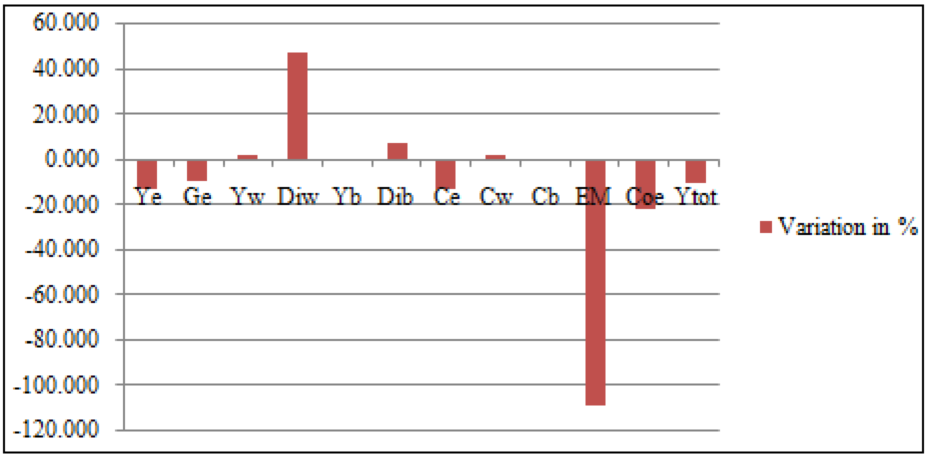


Figure 8: Percentage change in endogenous variables following the USD 2.0/tonne CO2 tax
Source: Prepared by us.

4.5. Scenario 5: 2, 5 USD/ton of CO2

The carbon tax of 2.5 USD/ton of CO2 has resulted in a decrease in the consumption of electricity, which has become much more expensive, and therefore a decrease in its production. Electricity consumption decreased by 16.710%, and its production by the same amount. The fact that electricity has a much higher carbon emission factor than the other products in the model, namely wheat and barley, has had a crowding out effect on income that will be spent on consuming these products rather than electricity, so that their consumption and therefore production will increase even though they too are taxed, The consumption and production of wheat will increase by 3.144%, and that of barley by 0.551%, but this increase in their production is less than the decrease in the production of electricity, which means that the overall production and therefore the overall income will decrease by 13.016%. This decrease in the consumption of electricity, which far exceeds the increase in the consumption of other products, will result in a 136.990% decrease in CO2 emissions, as electricity is much more polluting than the other goods considered in the model. This decrease in electricity production is accompanied by a decrease in the intermediate consumption of electricity in natural gas and coal of 11.431% for natural gas and 27.195% for coal, that of oil remaining unchanged since it is considered as a rigid production factor in this model. Similarly, the increase in wheat and barley production is accompanied by an increase in intermediate consumption of these products in diesel, of 59.156% for wheat and 9.699% for barley, an increase insufficient to counterbalance the decrease in emissions due to the decrease in electricity consumption.

Table 6: Variation in % of endogenous variables in the scenario 5 model

Variable	Variation in %
Ye	- 16, 710
Ge	- 11, 431
Yw	3, 144
Diw	59, 156
Yb	0, 551
Dib	9, 699
Ce	- 16, 710
Cw	3, 144
Cb	0, 551
EM	- 136, 990
Coe	- 27, 195
Ytot	- 13, 016

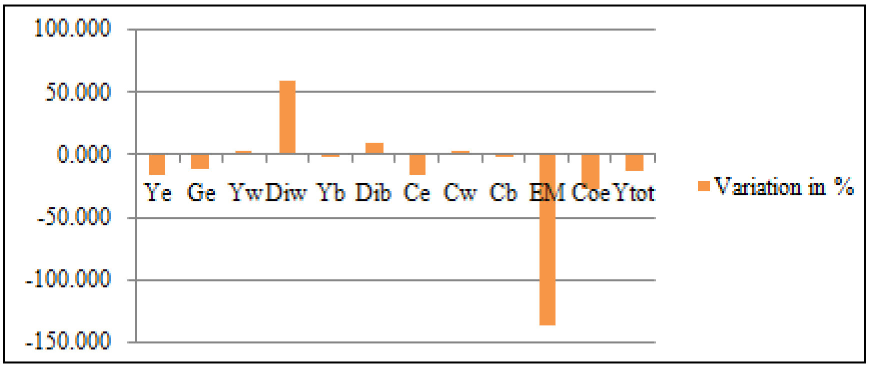


Figure 9: Variation in % of endogenous variables following the 2.5 USD/tonne CO2 tax
Source: Prepared by us

5. Conclusion

Contrary to what one might have thought, the carbon tax reduces the consumption and production of energy sectors only, in this case the electricity sector, while the production and consumption of other products even increase slightly. This is due to an eviction effect which means that income is diverted from the consumption of energy with too high a polluting factor to be redirected towards non - energy goods. In all scenarios there is a decrease in both global income and carbon emissions, and it is worth noting that with only a 0.5USD/ton of CO2 tax, emissions decrease by about 27.4% while global income only decreases by 2.6%. For a tax of 1USD/ton of CO2, these decreases are 54.8% for emissions and only 5.2% for global income and therefore GDP. We therefore recommend the introduction of a tax of 0.5USD/ton of CO2 as an effective policy to combat greenhouse gas emissions.

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