The effect of cap and trade policy on the economy, welfare and renewable energy for the Moroccan case: a partial equilibrium approach

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Abstract

In this paper, we are interested in cap-and-trade policy, or the implementation of pollution permits, as a mean to decrease CO2 emissions, which is the main cause of global warming, for the case of Morocco. To do so, we used a partial equilibrium model for the cereals market and the energy sector by simulating three scenarios of total emissions caps, namely a 1% decrease in emissions, a 5% decrease and a 7.5% decrease. We used this approach because we are concerned with one market, namely the cereals market and after designing the model wich is a system of equations capturing the interactions between fossil energy, renewable energy and cereals market, we log-linearized the model that we solved using matrix algebra with Octave. The results show that these forced emissions decreases have a very small effect on the decrease in income representing households welfare, remaining the same even in the 7.5% decrease scenario, as well as an increase in solar energy production and consumption. Therefore, a cap and trade system with a reasonnable cap will reduce emissions without affecting that much households welfare, while encouraging renewable energy production at the same time.

Key-words : Emissions, Partial equilibrium model, Cereals market, Energy, Cap and trade, Renewable energies.

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1. Introduction

In this study we are interested in the problem of global warming caused by greenhouse gases, which threatens our environment. One of the policies to decrease the emissions of CO2, which is the main greenhouse gas, is cap and trade, which consists in issuing pollution permits that can be traded on a market so that companies that pollute less can sell their permits to those that pollute more. In this way, the overall level of emissions is controlled by the state. We are concerned with the efficiency of environmental policies in the Moroccan case, in particular the cap and trade system in this study, wich focuses on the cereals market and energy sector with both fossil and renewable energy represented respectively by diesel and solar energy.

We propose to simulate this policy for the Moroccan case via three scenarios which are a decrease in emissions of 1%, 5% and 7.5%, in particular on the cereals market and the energy sector. We will proceed as follows : after this introduction, we will review the existing literature on the subject, then present our methodology, before exposing our data sources and economic model, then show the results of our model simulations, and finally draw the main conclusions.

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2. Literature review

Cap-and-trade is a policy that sets a cap on global emissions of a pollutant, such as carbon, and establishes a carbon market where companies can buy and sell tradable pollution permits or rights to pollute. Firms that have not reached the critical level of pollution can sell their permits to those that have reached their emissions cap. Most authors agree that this is an efficient and beneficial way to reduce pollution from an economic point of view, and we will present summaries of their work in what follows.

Paltsev et al. (2008), in 2007 the US Congress began considering a series of bills to introduce tradable permits to limit greenhouse gas emissions at the national level. MIT's Integrated Earth System Model (IGSM) and its economic component, the Emissions Projection and Policy Analysis (EPPA) model, were used to evaluate these proposals. The EPPA model predicts that US greenhouse gas emissions will double by 2050 in the absence of policy action. Globally, emissions from growing developing countries are expected to rise further.

Without controls, these emissions will cause global CO2 concentrations to rise from 380 ppmv today to about 550 ppmv in 2050 and to about 900 ppmv in 2100, resulting in global temperatures in 2100 3.5 to 4.5 degrees higher than Congress' most ambitious proposal wich could limit that increase to about 2°C, but only if other countries, including developing countries, also tightly manage greenhouse gas emissions. If larger cuts were made, the economic cost, as measured by change in total U.S. wealth, could range from 1.5% to almost 2% between 2040 and 2050, with an increase in the price of 2015 CO2 equivalent from $30 to $55 to $120 to $210 by 2050. While this price level would not seriously impede US GDP growth, it would result in far-reaching changes to the energy system.

With the goal of significantly reducing U.S. emissions by 2050, these proposals could result in prices ranging from $30 to $55 per tonne of CO2-e in 2015. It could rise from $120 to over $200 by 2050. If mitigation is presumed, it is expected to be just under 1.5-2% by 2050. If economic policymakers were not confident that policy would be introduced by 2050 without easing, the level of banking activity would fall slightly, leading to lower prices and costs in the early part of the period, and then prices and costs may rise. The banking industry is also highly dependent on its expectations of future technology, and the market may rate these prospects significantly differently than projected. An optimistic view of future technology will lead to lower prices for banking services and a reduction in his CO2 emissions in the short term.

According to Stavins (2008), the need for US domestic policy to take climate change seriously is becoming increasingly apparent. A cap-and-trade system is the best approach for the United

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States in the short to medium term. Cap-and-trade not only provides more certainty about emissions levels, but also provides an easy way to balance the necessarily uneven burden of climate policy. Adapting to other countries' climate policies is easy. It sidesteps the current political aversion to US taxes. It has been used successfully in the past. The system described here has several main characteristics. Setting upstream caps on CO2 emissions (carbon content measured at the point of fuel extraction, refining, distribution and import) and phasing in other greenhouse gases to limit the number of companies monitored while ensuring total coverage. Set a trend to gradually lower emissions caps over time, minimizing disruption and giving businesses and homes time to adapt. It also includes a mechanism to reduce cost uncertainty. These include bank and credit facility provisions, as well as cost containment mechanisms to protect against price volatility.

Like other market-based emission reduction schemes, the scheme described here reduces compliance costs by providing flexibility to regulators. However, rather than imposing specific measures on all sources, emissions can be reduced to some extent where they are most cost-effective. To illustrate the potential savings, he presented empirical cost estimates for two hypothetical emissions control pathways. The first is to stabilize CO2 emissions at 2008 levels by 2050, and the second is to reduce emissions from 2008 levels to 50 times 1990 levels by 2050. Both trajectories are in line with the oft-cited global goal of stabilizing the atmospheric CO2 concentration between 450-550 ppm if all nations take action. His analysis shows that both development paths have a significant but affordable impact on GDP levels. Generally less than 0.5 percent per year for less aggressive trajectories and up to 1 percent for more aggressive trajectories.

He et al. (2012) compare the effectiveness and efficiency of cap-and-trade and carbon tax measures in an intergenerational planning framework. Effectiveness refers to the ability of a policy to control carbon emissions, and efficiency is measured by seven criteria:

Average emission price, actual emissions, renewable energy portfolio, total electricity generation, total income for Genco and grid owners, economic welfare, and emissions-adjusted economic welfare. Cap-and-trade and four carbon tax policy alternatives are integrated into a game theory-based generation expansion planning model to assess the impact of new investment in renewable energy capacity. A case study was run on a 30-bus test system and numerical results highlight the strengths and weaknesses of these guidelines. A clear winner or loser could not be identified based on the numerical results of a case study of 30 bus networks.

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All policies present relative advantages and disadvantages based on various criteria. Neverthless, the following insights can be drawn :

Cap-and-trade is similar to UTn (nodal flat tax) and UT (flat tax) with different issuance limits. Cap-and-trade is equal to UT if there is a contribution in all periods and UTn if there is no contribution. Inconsistent incentives can result in different taxes and subsidies being imposed in different locations and over different periods of time. As a result, unnecessary costs are reduced and overall profits for Gencos and network owners are increased.

Chen et al. (2020) compare the impact of carbon taxes and cap-and-trade systems on clean innovation under static optimal models. First, cap-and-trade and carbon taxes both encourage clean innovation and emissions reductions. Second, cap-and-trade are more effective than carbon taxes in reducing emissions and promoting clean innovation. Furthermore, while companies suffer losses from carbon taxes, the impact of cap-and-trade schemes on corporate profits is uncertain depending on the carbon cap. In summary, they advocate cap-and-trade to address global climate change, but regulators need appropriate emissions caps and carbon trading to ensure cap-and-trade is effective. They have to choose the suitable carbon price and emissions cap.

They demonstrate and support the benefits of the cap-and-trade system. However, regulators should keep in mind that while CAT helps reduce emissions, emissions caps and carbon trading prices have a positive impact on corporate profits. A major problem for regulators is choosing appropriate emissions caps and carbon trading prices. Otherwise, the CAT system will lose regulatory validity. In addition, they propose capping CO2 emissions to improve the price of CO2 emissions. The relevant policy implications are to promote the CAT system and make reasonable cap allocations to ensure the effective operation of the CAT system.

Hu et al. (2020) say the debate between the two key mechanisms for reducing carbon emissions to combat global warming, cap-and-trade and carbon taxes, has been going on for years and is still unresolved. Either or both of these implementation strategies are primarily addressed at the national level, tailoring policy decisions to individual sectors, especially the emerging retrofit sector, which has great potential to reduce material and energy consumption need to adjust. Based on a closed supply chain model, they use a series of numerical studies to analyze the trade-offs between carbon taxes and cap-and-trade systems. Cap-and-trade shows that while managing carbon emissions, it is also good for cleanup.

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Producer profits, social welfare, and consumer surplus performance outperform the 'carbon tax' in 9, 8, and 6 of the 9 groups, respectively. Emissions trading losses can only be expected if the amount of emission permits is too high.

In addition, they examine two government-to-business subsidy strategies, direct subsidies and political bias, and find that both are useful, but their effects are roughly the same. The results provide useful insights into the industrial design of the CO2 reduction mechanisms in retrofitting and related fields.

In general, cap-and-trade is better suited for renovations than CO2 tax. In most cases, cap-and-trade wins in terms of economic performance, while carbon taxes are not seen as very beneficial to the economy. From an overall environmental performance perspective, cap-and-trade outperforms carbon taxes in reducing emissions, as long as governments keep caps at reasonable levels. As such, Cap and Trade is well positioned to help green the retrofit industry and encourage companies to transition to clean manufacturing.

Where repackaging companies are working to reduce their carbon emissions through cap-and-trade schemes and carbon taxes, G-to-E-S (government grants to companies) can further streamline business processes and reduce the production of repackaged products wich implicates less pollution, and cleaner production. A model developed to compare direct subsidies and policy biases provides guidance on how governments should implement the G-to-E-S under various carbon policies. If an emissions trading scheme is already in place, it would be best to introduce a cap-and-trade scheme with relatively low prices for carbon emissions into the retrofit industry. Otherwise, a carbon tax is a viable option.

Although most authors agree that cap-and-trade is an effective and economically advantageous way to reduce carbon emissions, there is no consensus in the literature. Indeed, there is a minority of works that conclude that cap-and-trade is an inefficient and disadvantageous policy for lowering carbon emissions. We present summaries of their papers in what follows.

Hovi and Holtsmark (2006) propose an internationally harmonized carbon tax-based system as an alternative to Kyoto's cap-and-trade approach. They explore and compare enforcement issues related to tax and cap-and-trade systems. They are trying to make two main points. First, both types of institutions need effective enforcement mechanisms. However, such mechanisms are unlikely to be introduced as part of a full participation system, as the political process leading to their introduction tends to significantly water down enforcement mechanisms. And even if this were somehow circumvented, countries that find compliance difficult or costly will almost certainly refuse to sign or ratify the resulting agreement.

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Second, the impact of non-compliance in tax systems is significantly different than the equivalent impact in cap-and-trade regimes. In a cap-and-trade system, emissions trading may leave the purchaser of allowances unattended. In particular, overselling of permits by one (or more) of the permitted export countries could completely undermine the environmental impact of this regime. In contrast, under a fiscal regime, one country's default cannot justify another's inaction. Therefore, an agreement based on a harmonized carbon tax will always have some effect, as long as at least one country complies.

An international climate agreement based on a flat CO2 tax is likely to be more effective than a cap-and-trade regime. The control system has other advantages as well. However, to achieve a high level of compliance, both types of regimes require effective enforcement mechanisms that are unlikely to coincide with everyone's participation.

It is therefore important to design an international regime that can effectively tackle climate change without the need for stringent enforcement mechanisms. Even if the tax system does not fully meet this requirement, the tax system is much less dependent on enforcement and therefore more favorable than the Kyoto cap-and-trade system.

Strand (2013) provides the first analysis of the 'political bloc' of fossil fuel importers implementing optimal climate policies, facing the (non-political) fringes of other fuel importers and bloc of exporters and getting the offset from the fringe. He compares carbon taxes and political bloc emissions trading schemes, both with effective offsetting mechanisms to reduce emissions in the surrounding region. Political spheres seem to prefer taxes over caps, as only taxes drive down fuel export prices, and the larger the political sphere, the greater the tendency. For political parties, it is also cheaper to pay compensation as part of the tax than as part of the cap.

The optimal compensation price for carbon tax is below the tax rate, but for caps and free trade permits, the compensation price should match the permit price. Both carbon and offset prices are higher with taxes than with caps when political blocs are small. If the political bloc is large, the compensation price can be higher based on the cap. Neighboring countries benefit from lower fuel import prices in the form of political mitigation measures, or carbon taxes.

Moreover, optimal carbon prices in political blocs are influenced by both climate (“Pigou”) and strategic motives, with political blocs influencing fuel prices for exporters through taxes and caps. A positive carbon tax will lead to lower fuel import prices, benefiting all fuel importing countries, including surrounding regions. Larger political blocs have higher taxes for two reasons:

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In that case, the "Pigou" element will be larger. And the strategic element is greater, so the tax will lower overall fuel demand and fuel export prices.

Additionally, he finds that fuel importers always prefer carbon taxes to emissions trading policies, mainly because fuel exporters charge lower prices for carbon taxes than for emissions trading schemes. Under a cap-and-trade policy, once capped, total fuel demand is less sensitive to fuel export prices than a carbon tax. This creates an incentive for monopoly exporters to set export prices higher under a cap-and-trade than a carbon tax, to the detriment of all importers. The offset market is also more profitable for coalitions because under a carbon tax in their model, since offset prices can be cheaper than the tax, while a united deal allows for cap-and-based domestic allowances and trading becomes impossible as price differentiation of offsets come into play.

Johnson (2007) notes that greenhouse gas regulatory instruments pose a policy dilemma: market-based instruments, such as cap-and-trade, serve to reduce regulatory costs; but because they do not guarantee that costs will be reduced to acceptable levels, it is impossible to set caps at sustainable levels. Emissions taxes provide cost certainty, but their relatively high cost makes it impossible to set tax rates at levels consistent with sustainability goals. There is, however, a simple solution to this dilemma: just as cap-and-trade uses free allocation of allowances to minimize regulatory costs, the cost of an emissions tax can be mitigated by refunding tax revenues in such a way that reducing emissions becomes cost-effective.

A refunded tax, such as cap-and-trade with free allocation, would be revenue neutral within the regulated industry. Marginal competitive incentives for commercializing emissions reduction technologies would not be diminished by the rebate, and the rebate could actually make it politically and economically feasible to increase incentives by an order of magnitude. Whereas cap-and-trade simply caps emissions to unsustainable levels and exposes the economy to extreme price volatility, emissions tax rebates provide a stable investment environment with sustainable incentives to reduce emissions over a long investment period.

Sabzevar et al. (2017) investigated analytically the impact of cap-and-trade policies on profitability. A game-theoretic Cournot model is considered, in which two competing firms produce goods and unwanted emissions on a single market. Production costs are non-linear and product demand is price sensitive. First, a relationship is created that maximizes each company's profit, given the price of the permit and the emission limit or cap. The equilibrium production volume of each company is determined on the premise that emissions trading will be conducted or not. Relationships are then established to study emissions caps, cap sharing between

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companies, and behavior depending on the price of carbon credits. In addition, it also determines the boundaries of the extent in which the permits transaction takes place.

The results indicate the conditions under which benefits increase or decrease when emissions regulations are tightened. In addition, it sets the conditions for companies to profit equally from emissions trading. Furthermore, the analysis shows that companies with the lowest emissions intensity never buy carbon credits if their operating costs are higher than their competitors. Therefore, cap-and-trade schemes do not necessarily encourage companies with the lowest emissions intensity to increase their market share.

The price-sensitive demand assumption is an important performance factor and therefore relevant in practice. With fewer products on the market, the price consumers are willing to pay rises. A decrease in production is offset by an increase in profit margins. The results suggest that emissions caps that limit production may actually lead to increased overall profits. A relationship was established to determine the total cap that yielded the maximum total profit for both fixed cap and cap-and-trade policies. The overall cap that yields maximum profit is lower for the cap-and-trade policy than for the fixed cap policy. However, overall profits are higher under a cap-and-trade policy despite lower overall limits.

This suggests that both the industry and the environment would benefit from a cap-and-trade system if overall caps were set optimally, but consumers ultimately paid more for their products. Another important aspect is the role of emission limits, which are commonly thought of as exogenous variables. All else being equal, the company with the lowest emissions intensity will have a relative advantage, as it will be able to produce more product before reaching emissions limits. However, if demand is price sensitive, maximizing production may not be optimal.

Therefore, under a cap-and-trade policy, companies with the lowest emissions are more likely to exceed their emissions, giving them the opportunity to sell carbon credits. Whether a permit can be sold depends on the price of the permit and the cap. Trade will only take place if it is beneficial to both companies. Relationships are established to set the range of acceptable prices used for trading, taking into account individual caps. Similarly, an issue price was calculated at which the profits of the transaction were divided equally between the permit buyer and seller. Also, a relationship was also established that determined the range of gross caps within which trades would take place, taking into account each firm's share of the total cap and favorable trading permit prices.

3. Methodology and model

3.1. Methodology and data sources

We used a partial equilibrium model with Cobb-Douglas type production and utility functions. We used 2022 data except for bioelectricity represented in our model by solar energy for which we used the 2020 value as provided by the 2020 energy balance published by the United Nations; we applied the percentage of solar energy to the value of bioelectricity given by the energy balance to find the total solar energy production. For the labor, capital, and diesel variables we used the data of the article « Energy Balance of Wheat and Barley under Moroccan Conditions » written by Mohamed Ramah & E. Houssain Baali in 2013 by updating the data to the cultivated surfaces of 2022 in respect to proportionality ; we made the assumption that factors of production are proportional to cultivated surface under the same conditions, assumption that is supported by the article of Ramah and Baali, 2013.

For the solar energy capital we determined the number of 4kw solar panels used to produce the amount of energy of the variable solar energy production given the fact that such a panel in one year produces 3,400kwh of electricity. For the intermediate consumption of solar energy we calculate it based on the fact that it represents 8,8% of the total intermediate consumption of energy by farmers since this is about the ratio of solar energy to total energy in Moroccan farms in 2021. The cultivated surfaces of wheat and barley and their prices in 2022 are easily found on the net on websites that we provide in the webography of this article.

Since our model makes predictions in the short run, we exogenized land and capital for wheat and barley. We also exogenize the emissions level since it is a cap and trade model and we model our simulations by fixing the cap. In addition, we have allowed more freedom of variation for intermediate diesel consumption by not setting its variation proportional to the production of a product, as these are the first variables to react to changes in fossil energy prices.

3.2. Model

We set up a partial equilibrium model with Cobb-Douglas type production functions for three products, solar energy or bioelectricity, wheat and barley. The maximization of the utility function, also of Cobb-Douglas type, gave 1st order conditions in the form of equations with the constraint of income modelled by making the assumption that total consumption will increase very very slightly based on the fact that from 2017 to 2022 the total consumption expenditure fluctuated around almost the same value. We linearized the equations of the model in order to solve them in variation form using matrix algebra in Octave.

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The model equations are as follows :

$Y_b = A_b . K_b^{\alpha_{K_b}}$ (1)

Y_b is the production of solar energy, A_b the total-factor productivity of solar energy, K_b its capital and only production factor in our model.

$Y_w = A_w . K_w^{\alpha_{K_w}} . L_w^{\alpha_{L_w}} . Z_w^{\alpha_{Z_w}} . DI_w^{\alpha_{DI_w}} . B_w^{\alpha_{B_w}}$ (2)

Y_w is the production of wheat, A_w the total-factor productivity of wheat, K_w its capital, L_w its labor, Z_w its cultivated surface, DI_w the diesel quantity used to produce wheat and B_w the quantity of solar energy used to produce wheat.

$Y_{bar} = A_{bar} . K_{bar}^{\alpha_{K_{bar}}} . L_{bar}^{\alpha_{L_{bar}}} . Z_{bar}^{\alpha_{Z_{bar}}} . DI_{bar}^{\alpha_{DI_{bar}}} . B_{bar}^{\alpha_{B_{bar}}}$ (3)

Y_{bar} is the production of barley, A_{bar} the total-factor productivity of barley, K_{bar} its capital, L_{bar} its labor, Z_{bar} its cultivated surface, DI_{bar} the quantity of diesel used to produce barley and B_{bar} the quantity of solar energy used to produce barley.

$C_b = Y_b - B_w - B_{bar}$ (4)

C_b is the final consumption of solar energy.

$C_w = Y_w$ (5)

C_w is the final consumption of wheat.

$C_{bar} = Y_{bar}$ (6)

C_{bar} is the final consumption of barley.

$B_w = a_{B_w} . Y_w$ (7)

B_w is the intermediate consumption of solar energy to produce wheat.

$B_{bar} = a_{B_{bar}} . Y_{bar}$ (8)

B_{bar} is the intermediate consumption of solar energy to produce barley.

$Y_{tot} = Y_b + Y_w + Y_{bar}$ (9)

Y_{tot} is the total production and represents both income and households welfare in our model.

The maximization of the consumer's utility which is equivalent to the maximization of the producer in this model gives us three first order conditions on the consumptions of the three products of this model which we include as equations of the model. Thus, we maximize :

$\Omega = C_b^{\alpha_{C_b}} . C_w^{\alpha_{C_w}} . C_{bar}^{\alpha_{C_{bar}}}$ (10)

Under constraint

$R \geq C_b + C_w + C_{bar}$ (11)

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And we obtain :

$$\alpha_{C_b}.C_b^{1-\alpha_{C_b}}.C_w^{\alpha_{C_w}}.C_{bar}^{\alpha_{C_{bar}}} = \lambda \ (12)$$

$$\alpha_{C_w}.C_w^{1-\alpha_{C_w}}.C_b^{\alpha_{C_b}}.C_{bar}^{\alpha_{C_{bar}}} = \lambda \ (13)$$

$$\alpha_{C_{bar}}.C_{bar}^{1-\alpha_{C_{bar}}}.C_b^{\alpha_{C_b}}.C_w^{\alpha_{C_w}} = \lambda \ (14)$$

λ is the Lagrange multiplicator associated to the Lagrangian of the above maximization problem.

$$C_{tot} = C_b + C_w + C_{bar} \ (15)$$

C_{tot} is the total final consumption of households and is exogenized in our model since we made the assumption that it increases very very slightly by about 0.000001% as said earlier.

$$EM = FE.(DI_w + DI_{bar}) \ (16)$$

EM is the level of total emissions and FE the factor of emission of diesel.

Table N°1 : Endogeneous variables of the model

Variable	Signification
Yb	Production of solar energy
Kb	Capital of solar energy
Lb	Labor of solar energy
Yw	Production of wheat
Diw	Consumption of diesel for wheat production
Bw	Consumption of bioelectricity for wheat production
Ybar	Production of barley
Dibar	Consumption of diesel for bioelectricity production
Bbar	Consumption of bioelectricity for barley production
Cb	Final consumption of solar energy
Cw	Final consumption of wheat
Cbar	Final consumption of barley
Ytot	Total production
Ctot	Total final consumption

Source : Authors.

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Table N°2 : Model parameters and their signification

Parameter	Signification
A_b	Total-factor productivity of solar energy
α_{Kb}	Share of capital in solar energy production
α_{Lb}	Share of labor in solar energy production
A_w	Total-factor productivity of wheat
α_{Kw}	Share of capital in wheat production
α_{Lw}	Share of labor in wheat production
α_{Zw}	Share of cultivated surface in wheat production
α_{DIw}	Share of diesel consumption in wheat production
α_{Bw}	Share of bioelectricity in wheat production
A_{bar}	Total-factor productivity of barley
α_{Kbar}	Share of capital in barley production
α_{Lbar}	Share of labor in barley production
α_{Zbar}	Share of cultivated surface in barley production
α_{DIbar}	Share of diesel consumption in barley production
α_{Bbar}	Share of bioelectricity in barley production
aBw	Share of intermediate consumption of bioelectricity in wheat production
aBbar	Share of intermediate consumption of bioelectricity in barley production
FE	Diesel emission factor
λ	Lagrange multiplier of objective function
α_{Cb}	Share of bioelectricity final consumption in total final consumption
α_{Cw}	Share of wheat final consumption in total final consumption
α_{Cbar}	Share of barley final consumption in total final consumption

Source : Authors.

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Table N°3 : Model parameters and their calibration

Parameter	Calibrated value
A_b	215321329.1
α_{Kb}	0.00025575427
A_w	4787911406
α_{Kw}	0.00000366414
α_{Lw}	0.0000000661328
α_{Zw}	0.00037037
α_{DIw}	0.000000480493
α_{Bw}	0.0148105
A_{bar}	1033144173
α_{Kbar}	0.00000365336
α_{Lbar}	0.0000002614131
α_{Zbar}	0.0008571429
α_{DIbar}	0.0000006428751
α_{Bbar}	0.0198157158
aBw	0.0148105072663466
aBbar	0.0198157157873016
FE	69.28645294725958
λ	0.386245574
α_{Cb}	0.2704971619385251
α_{Cw}	0.5918077723256803
α_{Cbar}	0.1376950657357946

Source : Authors.

4. Numerical analysis and results

We used three simulations represented by three scenarios, each corresponding to a carbon emissions cap, to analyze the impact of different levels of emissions caps on consumption and production of different products and household welfare. The first scenario simulates the decrease in emissions due to pollution permits, of 1%. The second simulates a 5% decrease and the third a 7.5% decrease. We present the results and interpretations of these three simulations in what follows.

4.1. Scenario 1 : Emissions diminution of 1%

The issuance of pollution permits setting the level of emissions at 1% less than the total emissions recorded in the previous year has the direct effect of reducing the intermediate consumption of diesel for both wheat and barley production. Thus DI_w decreases by 0.54667%, and DI_{bar} decreases by 2.4563%.

This decrease in fossil energy consumption led to an increase in intermediate consumption of solar energy, thus B_w increased by 3.3333e-07% and B_{bar} increased by 3.3333e-07%. This in turn led to the increase of both solar energy consumption C_b and solar energy production Y_b by 3.3333e-07% wich necessitated an increase in solar energy capital K_b by 1.1971e-03%. Since consumers maximize their utility, their consumption of different products increase leading to an increase in all productions and therefore total output, even if the intermediate consumption of diesel decreased, this is possible since the labor in different productions increased significantly.

Thus the consumption of wheat C_w increased by 3.3333e-07%, the consumption of barley Cbar increased by 3.3333e-07%, the productions of wheat and barley Y_w and Y_{bar} both increased by 3.3333e-07%. The labor of wheat production L_w increased by 8.9376% and the labor of barley production L_{bar} increased by 7.2903%. The total output or income representing welfare increased by 3.3333e-07%.

Table N°4 : Scenario 1 % variations

Variable	% Variation
Yb	3.3333e-07
Kb	1.1971e-03
Yw	3.3333e-07
Lw	8.9376e+00
DIw	-5.4667e-01
Bw	3.3333e-07
Ybar	3.3333e-07
Lbar	7.2903e+00
DIbar	-2.4563e+00
Bbar	3.3333e-07
Cb	3.3333e-07
Cw	3.3333e-07
Cbar	3.3333e-07
Ytot	3.3333e-07

Source : Authors.

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4.2. Scenario 2 : Emissions diminution of 5%

The issuance of pollution permits setting the level of emissions at 5% less than the total emissions recorded in the previous year has the direct effect of reducing the intermediate consumption of diesel for both wheat and barley production. Thus DI_w decreases by 3.5619%, and DI_{bar} decreases by 9.6198%.

This decrease in fossil energy consumption led to an increase in intermediate consumption of solar energy, thus B_w increased by 3.3333e-07% and B_{bar} increased by 3.3333e-07%. This in turn led to the increase of both solar energy consumption C_b and solar energy production Y_b by 3.3333e-07% wich necessitated an increase in solar energy capital K_b by 1.1971e-03%. Since consumers maximize their utility, their consumption of different products increase leading to an increase in all productions and therefore total output, even if the intermediate consumption of diesel decreased, this is possible since the labor in different productions increased significantly.

Thus the consumption of wheat C_w increased by 3.3333e-07%, the consumption of barley C_{bar} increased by 3.3333e-07%, the productions of wheat and barley Y_w and Y_{bar} both increased by 3.3333e-07%. The labor of wheat production L_w increased by 30.845% and the labor of barley production L_{bar} increased by 24.907%. The total output or income representing welfare increased by 3.3333e-07%.

Table N°5 : Scenario 2 % variations

Variable	% Variation
Yb	3.3333e-07
Kb	1.1971e-03
Yw	3.3333e-07
Lw	3.0845e+01
DIw	-3.5619e+00
Bw	3.3333e-07
Ybar	3.3333e-07
Lbar	2.4907e+01
DIbar	-9.6198e+00
Bbar	3.3333e-07
Cb	3.3333e-07
Cw	3.3333e-07
Cbar	3.3333e-07
Ytot	3.3333e-07

Source : Authors.

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4.3. Scenario 3 : Emissions diminution of 7.5%

The issuance of pollution permits setting the level of emissions at 7.5% less than the total emissions recorded in the previous year has the direct effect of reducing the intermediate consumption of diesel for both wheat and barley production. Thus DI_w decreases by 5.4464%, and DI_{bar} decreases by 14.097%.

This decrease in fossil energy consumption led to an increase in intermediate consumption of solar energy, thus B_w increased by 3.3333e-07% and B_{bar} increased by 3.3333e-07%. This in turn led to the increase of both solar energy consumption C_b and solar energy production Y_b by 3.3333e-07% wich necessitated an increase in solar energy capital K_b by 1.1971e-03%. Since consumers maximize their utility, their consumption of different products increase leading to an increase in all productions and therefore total output, even if the intermediate consumption of diesel decreased, this is possible since the labor in different productions increased significantly.

Thus the consumption of wheat C_w increased by 3.3333e-07%, the consumption of barley C_{bar} increased by 3.3333e-07%, the productions of wheat and barley Y_w and Y_{bar} both increased by 3.3333e-07%. The labor of wheat production L_w increased by 44.537% and the labor of barley production L_{bar} increased by 35.918%. The total output or income representing welfare increased by 3.3333e-07%.

Table N°6 : Scenario 3 % variations

Variable	% Variation
Yb	3.3333e-07
Kb	1.1971e-03
Yw	3.3333e-07
Lw	4.4537e+01
DIw	-5.4464e+00
Bw	3.3333e-07
Ybar	3.3333e-07
Lbar	3.5918e+01
DIbar	-1.4097e+01
Bbar	3.3333e-07
Cb	3.3333e-07
Cw	3.3333e-07
Cbar	3.3333e-07
Ytot	3.3333e-07

Source : Authors.

Conclusion

An imposed decrease in carbon emissions of 1% via a cap-and-trade system mainly affects the intermediate consumption of diesel, i.e. fossil fuels, which decreases significantly, leading to an increase of solar energy intermediate consumption instead by a predictable effect of substitution eventually increasing the consumption and production of solar energy wich increase the capital expenditure in solar energy representing bioelectricity in our model. This enables the increase of consumption of the different products that follows the maximisation of consumers utility leading to an increase in the productions of the same products and thus income and welfare wich is made possible through the increase of labor factors of both wheat and barley.

The same is true for a 5% decrease in carbon emissions, with all variations remaining the same except for intermediate diesel consumption that are directly affected by the policy and the variations of labor factors that enable the other variations to remain similar accross different levels of carbon caps, so the same could be said about the 7.5% decrease scenario with diesel intermediate consumptions decreasing more and labor factors increasing more.

Therefore, it is quite feasible to undertake a cap-and-trade policy starting with a cap that decreases carbon emissions by 1% and stop there if the level of emissions is deemed satisfactory especially for a country like Morocco which has a low level of emissions compared to other countries, or to raise the cap if necessary because our simulations have shown that a decrease in emissions of 5% or even 7.5% has a very small effect on income and thus household welfare while promoting the use of solar energy representing renewable energies in our model.

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