The Effect of a Carbon Tax on the Economy, Welfare and Emissions in Morocco: A Computable General Equilibrium Approach

Mohamed Adib Ed-daoudi[1], Kenza Oubejja[2]

[1]Mohamed 5 University of Rabat
Email: *madibeddaoudi[at]gmail.com*

[2]Mohamed 5 University of Rabat
Email: *kenza_oubejja[at]yahoo.fr*

Abstract: ***In this paper, we are interested in the issue of using a carbon tax as a policy to address the increasing CO2 emissions in the case of Morocco. To do so, we used a computable general equilibrium model of the PEP (1-1) type with 2018 data, and we simulated two scenarios, the first with a tax of 50 MAD/ton of CO2 and the second with a tax of 75 MAD/ton of CO2. The second scenario yields a larger decrease in carbon emissions than the first; however the decreases in GDP and welfare are significantly larger. Overall, both rates are effective, and it remains for policy makers to choose the best scenario according to their priorities.***

Keywords: Carbon tax, emissions, GDP, welfare, computable general equilibrium model

JEL classification: C68, E16, H21, Q58.

1. Introduction

We are interested in the issue of the environment, and the pollution caused by greenhouse gases responsible for global warming which will have unfortunate consequences on our planet if it is not countered by adequate and effective environmental policies, and this as soon as possible. One of these policies is the carbon tax, which we propose to study for the Moroccan case through the use of a computable general equilibrium model of type PEP (1-1).

We ask what is the impact of a carbon tax of 50 MAD/ton of CO2 and then 75 MAD/ton of CO2 on the economy, i.e. GDP and the main macroeconomic aggregates, on carbon emissions and on household welfare. To do so, we proceed as follows, after this introduction, we will explore the existing literature on the subject, expose our methodology and economic model, show the results of our model simulations, and finally draw the main conclusions.

2. Literature Review

One of the major issues facing any country wishing to implement a carbon tax is the apprehension that the tax could negatively impact GDP and/or household welfare. Some authors have found that the decrease in GDP and/or household welfare is minimal following the implementation of a carbon tax while others have found that the opposite is true. In the following we will present summaries of some of the work that has found that the carbon tax has a minimal impact on GDP and or household welfare.

Devarajan et al. (2011) find that developing countries may not have the administrative capacity to levy a "pure" carbon tax, and then compare the impact of alternative energy taxes to that of a carbon tax in an economy with multiple distortions. They use a disaggregated computable general equilibrium (CGE) model of the South African economy and simulate a range of tax policies that reduce CO2 emissions by 15%. Consistent with a "first-best" economy, a carbon tax will have the lowest marginal abatement cost. But the relationship between a tax on energy products and a tax on pollution-intensive products depends critically on other distortions in the system and structural rigidities in the economy. They show that if South Africa were able to remove distortions in the labor market, the cost of carbon taxation would be negligible. They find that the welfare costs of significantly reducing CO2 emissions are quite low. In general, the more targeted the tax is on carbon emissions, the lower the cost. If a carbon tax is feasible, it will have the lowest marginal abatement cost by a substantial amount compared to other tax instruments.

Moreover, the welfare losses from a carbon tax are small, regardless of the production substitution elasticities used in this analysis. If the revenues generated can be used to reduce pre-existing tax distortions, the net welfare cost becomes negligible. However, they find that a carbon tax is regressive: low-income households have a high expenditure share on commodities whose prices rise with a carbon tax and are therefore penalized by a carbon tax. If a carbon tax is not feasible, a tax on sales of energy inputs may be the best instrument: it has a higher overall welfare cost than a carbon tax, but a less regressive impact, given the existing distortions in the economy.

Lu et al (2010) note that under the pressure of global warming, it is imperative for the Chinese government to impose effective policy instruments to promote energy conservation and carbon emission reduction at the national level. The carbon tax, which is one of the most important incentive-based policy instruments, has been highly controversial in China. They explore the impact of the carbon tax on the Chinese economy, as well as the dampening effects of complementary policies, by constructing a dynamic recursive general equilibrium model. The model can describe the new equilibrium for each independent sequential period (e.g., one year) after the imposition of the carbon tax and complementary policies, and thus describe the long-term impacts of the policies.

They show that the carbon tax is an effective policy tool because it can decrease carbon emissions with a slightly negative impact on economic growth; decreasing indirect taxation in the interim of the carbon tax will help to decrease the negative impact of the tax on output and competitiveness; and subsidizing households in the interim will help to stimulate their consumption. As a result, complementary policies used in conjunction with the carbon tax will help cushion the negative effects of the carbon tax on the economy. The dynamic analysis of the CGE shows that the effect of the carbon tax policy on GDP is relatively small, but the decrease in carbon emissions is relatively large.

Guo et al. (2014) apply a computable general equilibrium model to study the impacts of a carbon tax on China's economy and carbon emissions based on China's 2010 input-output table. In order to obtain robust simulation results, the authors then disaggregate the energy sectors into eight departments based on energy use characteristics. They show that a moderate carbon tax would significantly decrease carbon emissions and fossil energy consumption and would slow the pace of economic growth by a minor amount. However, a high carbon tax has a significant negative impact on China's economy and social welfare.

In addition, a significant carbon tax would lead to marked price changes in China. Among the fossil fuels used, decreasing coal consumption would have the greatest impact on decreasing carbon emissions, and the ad valorem duty rate for coal would be the highest after a carbon tax is levied because it has the highest carbon emission coefficient. As a result, China should make efforts to promote clean coal technology, which can be crucial for reducing carbon emissions. Moreover, collecting a carbon tax would improve the use of clean energy, which would be an effective way to decrease carbon emissions. Therefore, the Chinese government should formulate the regulations and adopt a carbon tax as soon as possible in order to achieve its goal of decreasing carbon emissions and make a greater contribution to climate change mitigation.

Ed-daoudi and Oubejja (2021) used a partial equilibrium model analyzing the impact of a carbon tax on the cereals market in morocco with one sector of energy wich is electricity that emitted carbon, and found that a reasonable carbon tax can decrease significantly carbon enissions without decreasing GDP that much.

Wissema and Dellink (2007) develop a computable general equilibrium model with specific details on energy taxation and use to quantify the impact of implementing energy taxation to decrease carbon dioxide emissions in Ireland. Baseline data combining physical energy and emissions data with economic data in the form of a social accounting matrix (SAM) had to be compiled from a variety of data sources, as the SEEA energy and pollution accounts are not available for Ireland. They find that the target of reducing energy-related CO2 emissions in Ireland by 25.8% from 1998 levels can be achieved with a carbon tax of €10-15 per tonne of CO2.

While fuel switching is important to achieving the goal, this outcome is more sensitive to substitution opportunities for producers who shift away from energy use. Welfare would decline, but only by small percentages. Production and consumption patterns would change more significantly, with a shift in demand from high-emission fuels to low-carbon energy sources and from energy to other commodities. They confirm that a carbon energy tax leads to greater emissions reductions than an equivalent flat energy tax. The latter has a greater negative impact on the least polluting energy sectors, while the carbon tax strongly stimulates the use of renewable energy and reduces the use of peat and coal. The new SCM, model and application to energy taxes contribute to a more informed debate on environmental policy in Ireland.

Although fuel switching is an important element in achieving the target, the sensitivity analysis shows that this outcome is responsive to substitution opportunities for producers who forego energy use. Greater substitution opportunities cause emissions to respond more strongly to a given tax level, so that the goal can be achieved with lower tax levels. In comparison, a flat tax on energy, as currently adopted by many countries, must be much higher to achieve the same goal of lowering emissions, because it does not provide an incentive to substitute "cleaner" fuels for carbon-intensive ones.

In the above articles, the authors found that the carbon tax has a minimal impact on GDP and welfare. However, this position is not unanimous, as other authors have found that the carbon tax has a significant negative impact on GDP and/or welfare. We will present summaries of their work in what follows.

Liu et al. (2018) develop a computable general equilibrium (CGE) model for the province of Saskatchewan that is first developed to examine and analyze a range of both direct and indirect socioeconomic impacts of a carbon tax. The energy sector is then disaggregated by production structure and energy use pattern to provide robust results. Different carbon tax rates are simulated to quantify the interrelationships between the carbon tax, economic growth, and GHG emission reductions. Extensive examinations are also conducted to study some other macroeconomic impacts and the responses of specific economic sectors. They show that the change in GDP is primarily 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 largest GHG emissions of any sector. This means that clean coal and petroleum technologies could be the critical issues for achieving provincial and national environmental and economic goals. They expect that the results will provide a solid foundation to support the implementation of an effective Canada-wide carbon pricing strategy.

They find that a carbon tax would decrease greenhouse gas emissions while contracting the economy. A further increase in the carbon tax rate will result in marked decreases in GDP. This indicates 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.

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 be significantly different in different periods. Furthermore, the effects of different carbon taxes on different sectors of the tourism industry are also quite different.

They use CGE modeling and perform a comprehensive 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 levying a carbon tax can effectively decrease 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 to China's tourism industry due to the reduction in tourism's contribution to the national economy and the decrease in tourism employment. 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 run than in the long run. In addition, the impacts of a carbon tax vary considerably across tourism sectors.

Martins et al (1992) investigate the costs of reducing CO2 emissions by comparing the results of six global models consisting of a set of standardized reduction scenarios. He highlights regional differences in carbon tax curves up to the middle of the next century. A number of methodological tools are developed for this purpose that can explain the main mechanisms at work in GREEN. The welfare and GDP costs associated with emission reductions are also assessed.

The simulations indicate a wide regional variation in both carbon tax levels and in the welfare losses required to achieve a given emissions reduction target. Taxes tend to be lower in less developed regions that use coal more intensively than other regions. Welfare losses, as measured by real household income, are around 3-4% by 2050 for the average OECD country in the most stringent scenario. Energy-exporting LDCs experience the highest welfare losses because they suffer both the costs of imposing the tax and an additional reduction in revenue from a significant contraction in their oil exports to other regions. Measured by GDP losses, the costs are smaller but still reach 2.2 percent for the OECD average over the period 1990-2050 under the most stringent scenario. The different regional patterns can be explained by a simple index that summarizes the main drivers of a carbon tax.

3. Methodology and model

3.1 Methodology

The social accounting matrix (SAM) used in this work synthesizes Moroccan economic activity for the year 2018. The construction of this matrix is made on the basis of the one published by the High Commission for Planning (HCP) in 2018 (semi-definitive matrix) while referring to the national accounts namely the Resources and Employment Table (TRE) and the Integrated Economic Accounts Table (TCEI) for the same year. The disaggregation of account C01 of the SAM into natural gas and coal (oil being imported refined in its entirety), is done with the help of the Moroccan energy balance of 2018 as published by the United Nations, as well as the calculation of the emission factors of the polluting products is done with the help of the SAM jointly with the energy balance.

The nomenclature used for the SAM accounts is that of the 1993 System of National Accounts. The matrix of the Moroccan economy presents 71 accounts divided into six blocks. The first block includes two production factor accounts (capital and labor). The second block includes four economic agent accounts (households, firms, government and the rest of the world) with a decomposition of the government account into three accounts, namely direct taxes, the tax on imports and indirect taxes (the carbon tax is calculated independently by the model). The tax on exports is non-existent in Morocco and therefore absent from our model. The third block contains 21 industry accounts. The fourth block contains 23 composite product accounts, while the fifth block contains 17 exported product accounts. Finally, the last block includes two accumulation accounts, including Gross Fixed Capital Formation (GFCF) and changes in inventories.

We propose to adapt the PEP (1-1) model (Decaluwé et al., 2009) to the structure of the Moroccan economy in order to evaluate the environmental and economic implications of different carbon tax rates on GHG emissions. It is a static neoclassical model based on the Walrasian theory. Markets operate in an environment of pure and perfect competition where the decisions of economic agents are based on an optimization program of their objectives under specific constraints. The model considers only relative prices (real prices) which are expressed in relation to the price of an arbitrarily chosen good (Decaluwé et al., 1986). The CGE model that we adopt includes 8 blocks of equations, namely :

- The production block;
- The income, savings and inter-institutional transfers block;

- The demand block;
- The supply and foreign trade block;
- The price block;
- The block of equilibrium equations and macroeconomic aggregates;
- The household welfare block;
- The block of CO2 emissions.

We are interested in the quantities of CO2 emitted as a result of intermediate consumption and private consumption of the following products: natural gas, coal and oil, by multiplying their consumption levels by the emission factors of each of the products. We have adopted a classical closure that assumes that the value of investment adjusts to the level of available savings in order to satisfy the equality between these two variables. Moreover, public consumption is considered exogenous and adjusts with public savings, which is an endogenous variable. International prices are assumed to be given since Morocco is a price taker and has no influence on international prices.

3.2 Model

The model we used is composed of equations grouped in 8 blocks as follows:

The production block :

$$XS_j = VA_j / v_j$$

$$CI_j = io_j XS_j$$

$$VA_j = B_j^{VA}\left[B_j^{VA} LDC_j^{-\rho_j^{VA}} + (1-\beta_j) KDC_j^{-\rho_j VA}\right]^{-1/\rho_j^{VA}}$$

$$LDC_j = \left[\frac{\beta_j^{VA}}{1-\beta_j^{VA}} \cdot \frac{RC_j}{WC_j}\right]^{\sigma_j^{VA}} KDC_j$$

$$KDC_j = \left[1 - \frac{\beta_j^{VA}}{\beta_j^{VA}} \cdot \frac{WC_j}{RC_j}\right]^{\sigma_j^{VA}} LDC_j$$

$$DI_{i,j} = a_{ij} CI_i$$

- The income, savings and inter-institutional transfers block:

$$YHL = w \sum_j LDC_j$$

$$YHK = \lambda_{h,ag} \sum_j R_j KDC_j$$

$$YHTR = \sum_{ag} TR_{h,ag}$$

$$YDH = YH - TDH$$

$$CTH = YDH - SH - \sum_{ag} TR_{ag,h}$$

$$SH = PIXON^{\eta} sh0 + sh1\, YDH$$

$$YF = YFK + YFTR$$

$$YFK = \lambda_{firm}^{RK} \sum_j R_j KDC_j$$

$$YFTR = \sum_{ag} TR_{ag,firm}$$

$$YDF = YF - TDF$$

$$SF = YDF - \sum_{ag} TR_{ag,firm}$$

$$YG = YGK + TDH + TDF + TPRCTS + YGTR + \sum_j TIP_j$$

$$YGK = \lambda_{gov}^{RK} \sum_j R_j KDC_j$$

$$TPRCTS = TICT + TIMT$$

$$YGTR = \sum_{ag} TR_{gov,ag}$$

$$TDH = PIXON^{\eta} ttdh0 + ttdh1 YH$$

$$TDF = PIXON^{\eta} ttdf0 + ttdf1 YF$$

$$TIP_j = ttip_j PP_j XST_j$$

$$TIC_i = ttic_i [PL_i DD_i + (1 + ttim_i) PWM_i e\, IM_i]$$

$$TIM_i = ttim_i PWM_i e\, IM_i$$

$$SG = YG - \sum_{ag} TR_{ag,gov} - G$$

$$YROW = e \sum_i PWM_i IM_i + \sum_{ag} TR_{row,ag}$$

$$SROW = YROW - \sum_i PE_i^{fob} EXD_i - \sum_{ag} TR_{ag,row}$$

$$SROW = -CAB$$

$$TR_{ag,h} = \lambda_{ag,h}^{TR} YDH$$

$$TR_{gvt,h} = PIXON^{\eta} tr0_h + tr1_h YH$$

$$TR_{ag,f} = \lambda_{ag,f}^{TR} YDF$$

$$TR_{ag,gvt} PIXON^{\eta} TR_{ag,gvt}^{0}$$

$$TR_{ag,row} = PIXON^{\eta} TR_{ag,row}^{0}$$

- The demand block :

$$PC_i C_i = PC_i C_i^{MIN} + \gamma_i^{LES}\left(CTH - \sum_i PC_i C_i^{MIN}\right)$$

$$FBCF = IT - \sum_i PC_i VSTK_i$$

$$PC_i INV_i = \gamma_i^{INV} FBCF$$

$$PC_i CG_i = \gamma_i^{G} G$$

$$DIT_i = \sum_i DI_i$$

- The supply and foreign trade block :

$$XST_j = B_j^{XT}\left[\sum_i \beta_{j,i}^{XT} XS_{j,i}^{\rho_j^{XT}}\right]^{1/\rho_j^{XT}}$$

$$XS_{j,i} = \frac{XST_j}{(\beta_j^{XT})^{1+\rho_j^{XT}}}\left[\frac{p_{j,i}}{\beta_{j,i}^{XT} PT_j}\right]^{\sigma_j^{XT}}$$

$$XS_{j,i} = B_{j,i}^{X}\left[B_{j,i}^{X} EX_{j,i}^{\rho_{j,i}^{X}} + (1-\beta_{j,i}^{X}) DS_{j,i}^{\rho_{j,i}^{X}}\right]^{1/\rho_{j,i}^{X}}$$

$$EX_{j,i} = \left[\frac{1-\beta_{j,i}^{X}}{\beta_{j,i}^{X}} \frac{PE_i}{PL_i}\right]^{\sigma_{j,i}^{X}} DS_{j,i}$$

$$EXD_i = EXD_i^{O}\left(\frac{ePWX_i}{PE_i^{fob}}\right)^{\sigma_i^{XD}}$$

$$Q_i = B_i^{M}\left[\beta_i^{M} IM_i^{-\rho_i^{M}} + (1-\beta_i^{M}) DD_i^{-\rho_i^{M}}\right]^{-1/\rho_i^{M}}$$

$$IM_i = \left[\frac{\beta_i^{M}}{1-\beta_i^{M}} \frac{PD_i}{PM_i}\right]^{\sigma_i^{M}} DD_i$$

- The price block :

$$PP_j = \frac{PVA_j VA_j PC_j CI_j}{XST_j}$$

$$PT_j = (1 + ttip_j) PP_j$$

$$PCI_j = \frac{\sum_i PC_i DI_{i,j}}{CI_j}$$

$$PVA_j = \frac{WC_j LDC_j + RC_j KDC_j}{VA_j}$$

$$PT_j = \frac{\sum_i P_{ji} XS_{ji}}{XST_j}$$

$$P_{j,i} = \frac{PE_i EX_{j,i} + PL_i DS_{j,i}}{XS_{j,i}}$$

$$PE_i^{fob} = PE_i$$

$$PD_i = (1 + ttic_i + tc_i) PL_i$$

Paper ID: SR24714153004 DOI: https://dx.doi.org/10.21275/SR24714153004

$$PM_i = (1 + ttic_i)[(1 + ttim_i)ePWM_i]$$

$$PC_i = \frac{PM_i IM_i PD_i DD_i}{Q_i}$$

$$PIXCON = \frac{\sum_i (PC_i \sum_h C_{i,h}^O)}{\sum_i (PC_i^O \sum_h C_{i,h}^O)}$$

- The block of equilibrium equations and macroeconomic aggregates :

$$Q_i = C_i + CG_i + INV_i + VSTK_i + DIT_i$$

$$\sum_j LD_j = LS$$

$$\sum_j KD_j = KS$$

$$IT = SH + SF + SG + SROW$$

$$\sum_j DS_{j,i} = DD_i$$

$$\sum_j EX_{j,i} = EXD_i$$

$$GDP^{BP} = \sum_j PVA_j VA_j + \text{TIPT}$$

$$GDP^{MP} = GDP^{BP} + TPRCTS$$

$$GDP^{IB} = \sum_{l,j} W_l LD_{l,j} + \sum_{k,j} R_{k,j} KD_{k,j} + TPRODN + TPRCTS$$

$$GDP^{FD} = \sum_i PC_i (C_i + CG_i + INV_i + VSTK_i) + \sum_i PE_i^{fob} EXD_i - e\sum_i PWM_i IM_i$$

- The household welfare block:

We used as a measure of household welfare noted U, their total consumption of products in volume (quantity).

$$U = CTH_h^{REAL} = \frac{CTH_h}{PIXCON}$$

$$CTH_h = \sum_i C_{i,h}$$

- The block of CO2 emissions:

$$TQCO2 = \sum_{h,i} FE_i . C_{i,h} + \sum_{j,i} FE_i . DI_{j,i}$$

4. Numerical analysis and results

To analyze the impact of different carbon tax rates on the main macroeconomic aggregates, including GDP, as well as on CO2 emissions and household welfare, we used two simulations represented by two scenarios. The first scenario is the implementation of a carbon tax of 50 MAD/ton of CO2, and the second is the implementation of a carbon tax of 75 MAD/ton of CO2. We present the results and interpretation of these two simulations in what follows.

4.1 Scenario 1 : 50 MAD/tonne de CO2

A carbon tax of 50 MAD/ton of CO2 results in an increase in the prices of domestic products and consequently a decrease in their demand, i.e. consumption and investment, the percentage decreases of which by product are given in tables 1 and 2:

Table 1: Variation of consumption in % after a carbon tax of 50 MAD/ton of CO2.

Product	Variation of consumption in %
AGRP	-0,085452555
PAQP	-0,349587265
C03P	-0,233602812
IATP	-0,119746924
ITCP	-0,122299774
ICPP	-0,177732427
IMMP	-0,093879759
AINP	-0,134862487
RPEP	-0,092336257
EAUP	-0,702636666
BTVP	-0,114894186
COMP	-0,148115445
HRSP	-0,139754278
TRAP	1,977781707
PTCP	-0,114288586
AFAP	-0,010685128
IMLP	-0,032102778
ADMP	-0,068692128
MNOP	-0,010400432
OPOP	-0,005349105

Table 2: Variation of investment in % after a carbon tax of 50 MAD/ton of CO2.

Product	variation of investment in %
AGRP	-0,396103746
ITCP	-0,379195978
IMMP	-0,339204764
AINP	-0,396923515
BTVP	-0,37652435
IMLP	-0,254361341
OPOP	-0,215440916

The increase in price of energy has the effect of greatly diminishing the intermediary consumption of oil by the branch of activity of transport because oil is its main intermediary consumption which in turn decreases the price of transport production leading to a decrease in its local price and finally an increase in its consumption (the numerical value of this increase is given above in table 1).

In addition, the tax through intermediate consumption makes that the branches of activity produce and or export more or less according to whether it is more or less advantageous to offer more the product on the local market and or on the external market. The mechanism by which intermediary consumption affects production and export is that for the branches of activity having a large part of their intermediary consumption composed by energy (oil, gas or coal), the rise of energy price lowers their intermediary consumption of energy and thus production and export (if they export). The local production of oil decreases with the rise of its local price which encourages and increases its export since there is no carbon tax on exports.

On the other hand, the opposite happens for branches that have low intermediary consumption of energy relatively to their total intermediary consumption, so their production and export increase (variations in exports are given in table 3 and variations in production in table 4, both for scenario 1). As for the imports, the increase of commodity domestic price tends to increase its import if it is important especially if the domestic demand for the product produced locally increases greatly and if the domestic price rises while the domestic demand decreases, imports decrease (variations of imports for scenario 1 are given in table 5). The following tables illustrate numerically these variations:

Table 3: Variation of exports in % after a carbon tax of 50 MAD/ton of CO2.

Product	Variation of exports in %
AGRP	0,666340012
PAQP	1,286172655
C02P	0,614456596
C03P	1,502130538
IATP	0,111059118
ITCP	0,111752413
ICPP	0,190052144
IMMP	0,086086837
AINP	0,320279266
RPEP	0,054687174
EAUP	-0,203104752
HRSP	-0,19261064
TRAP	-4,190064484
PTCP	-0,103628931
AFAP	-0,613218054
IMLP	-0,177426542
OPOP	0,168981197

Table 4: Variation of domestic production in % after a carbon tax of 50 MAD/ton of CO2.

Product	Variation of domestic production in %
AGRP	1,422907349
PAQP	2,864065718
C02P	1,709181886
C03P	2,911890332
IATP	0,367780291
ITCP	0,456261569
ICPP	0,89777312
IMMP	0,266203332
AINP	0,747200511
RPEP	-1,388834918
EAUP	-0,395642478
BTVP	-0,36630925
COMP	-0,27646203
HRSP	-0,184511328
TRAP	-12,44058357
PTCP	-0,191040629
AFAP	-1,392120592
IMLP	-0,419191788
ADMP	-0,003245036
MNOP	0,07130185
OPOP	0,041693801

Table 5: Variation of imports in % after a carbon tax of 50 MAD/ton of CO2.

Product	Variation of imports in %
AGRP	1,633926462
PAQP	3,725493815
GASP	-0,299579281
COALP	-0,299602839
C02P	2,198941428
C03P	3,545233813
IATP	0,531816909
ITCP	0,712768251
ICPP	1,483333288
IMMP	0,452206501
AINP	1,088185993
RPEP	-0,369312318
EAUP	1,599837944
HRSP	0,044272458
TRAP	-20,02929377
PTCP	-0,043648547
AFAP	-1,561471458
IMLP	-0,539152101
OPOP	-0,149154293

Finally, the decrease in consumption of almost all products results in a decrease in welfare of 0.00105%, which is negligible compared to the decrease in emissions of 0.43374%, which is due to a decrease in consumption and intermediate consumption of CO2 emitting products, namely oil, natural gas and coal. The global decrease in production in prices, all products included, has induced a decrease in GDP of 0.04059%, which is also negligible compared to the decrease in emissions.

4.2 Scenario 2: 75 MAD/ton of CO2

A carbon tax of 75 MAD/ton of CO2 results in an increase in the prices of domestic products and consequently a decrease in their demand, i.e. consumption and investment, the percentage decreases of which by product are given in the following tables (table 6 for consumption variations and table 7 for investment variations, both for scenario 2):

Table 6: Variation of consumption in % after a carbon tax of 75 MAD/ton of CO2.

Produit	Variation of consumption in %
AGRP	-0,133635387
PAQP	-0,455990094
C03P	-0,375458296
IATP	-0,189735405
ITCP	-0,173047516
ICPP	-0,248342812
IMMP	-0,145382631
AINP	-0,210046689
RPEP	-0,155184392
EAUP	-1,058297482
BTVP	-0,178307799
COMP	-0,241575825
HRSP	-0,187558563
TRAP	1,740158481
PTCP	-0,178596901
AFAP	-0,036972833
IMLP	-0,058734376
ADMP	-0,125830647
MNOP	-0,031007769
OPOP	-0,049536014

Table 7: Variation of investment in % after a carbon tax of 75 MAD/ton of CO2.

Produit	Variation of investment in %
AGRP	-0,523068703
ITCP	-0,471090268
IMMP	-0,432077507
AINP	-0,523124009
BTVP	-0,49041242
IMLP	-0,314019381
OPOP	-0,301027033

The increase in price of energy has the effect of greatly diminishing the intermediary consumption of oil by the branch of activity of transport because oil is its main intermediary consumption which in turn decreases the price of transport production leading to a decrease in its local price and finally an increase in its consumption (the numerical value of this increase is given above in table 6).

Moreover, the tax through intermediate consumption makes that the branches of activity produce and or export more or less according to whether it is more or less advantageous to offer more the product on the local market and or on the external market. The mechanism by which intermediary consumption affects production and export is that for the branches of activity having a large part of their intermediary consumption composed by energy (oil, gas or coal), the rise of energy price lowers their intermediary consumption of energy and thus production and export (if they export). The local production of oil decreases with the rise of its local price which encourages and increases its export since there is no carbon tax on exports.

On the other hand, the opposite happens for branches that have low intermediary consumption of energy relatively to their total intermediary consumption, so their production and export increase. As for the imports, the increase of commodity domestic price tends to increase its import if it is important especially if the domestic demand for the product produced locally increases greatly and if the domestic price rises while the domestic demand decreases, imports decrease. The following tables illustrate numerically these variations:

In addition, the tax through intermediate consumption makes that the branches of activity produce and or export more or less according to whether it is more or less advantageous to offer more the product on the local market and or on the external market. This also affects imports, whether to produce locally or to export or simply for consumption or investment. Consequently, variations in production, exports, consumption and investment are reflected in imports, which vary upwards or downwards accordingly. Thus, domestic production, exports and imports vary as follows (table 8 for exports variations, table 9 for imports variations and table 10 for domestic production variations, all for scenario 2):

Table 8: Variation exports in % after a carbon tax of 75 MAD/ton of CO2.

Product	Variation exports in %
AGRP	0,872403891
PAQP	1,315839725
C02P	0,609366513
C03P	1,426077565
IATP	0,08179259
ITCP	0,11181312
ICPP	0,126527765
IMMP	0,068815568
AINP	0,231486917
RPEP	0,0824123
EAUP	-0,314706582
HRSP	-0,20345296
TRAP	-4,277690337
PTCP	-0,125679317
AFAP	-0,599550715
IMLP	-0,151911424
OPOP	0,154643398

Table 9: Variation of imports in % after a carbon tax of 75 MAD/ton of CO2.

Product	Variation of imports in %
AGRP	2,152616218
PAQP	3,839770708
GASP	-0,487421009
COALP	-0,487423564
C02P	2,099016783
C03P	3,745136036
IATP	0,573275945
ITCP	0,690297894
ICPP	1,547096174
IMMP	0,381112885
AINP	1,069095801
RPEP	-0,408317005
EAUP	2,341344702
HRSP	-0,003250651
TRAP	-19,73060014
PTCP	-0,058676777
AFAP	-1,670010111
IMLP	-0,665814853
OPOP	-0,215777921

Table 10: Variation of domestic production in % after a carbon tax of 75 MAD/ton of CO2.

Product	Variation of domestic production in %
AGRP	1,859048143
PAQP	2,806650842
C02P	1,652765333
C03P	2,75811402
IATP	0,346642795
ITCP	0,436402989
ICPP	0,855259164
IMMP	0,193503928
AINP	0,601282098
RPEP	-1,967859533
EAUP	-0,63411615
BTVP	-0,476417661
COMP	-0,343423396
HRSP	-0,228408865
TRAP	-12,82550691
PTCP	-0,25436247
AFAP	-1,432986167
IMLP	-0,46999487
ADMP	-0,016233203
MNOP	0,10459566
OPOP	-0,010222839

Finally, the decrease in consumption of almost all products has resulted in a decrease in welfare by 0.08121%, which is low compared to the decrease in emissions by 0.54943%, which is due to a decrease in consumption and intermediate consumption of CO2 emitting products, namely oil, natural gas and coal. The global decrease in production in prices, all products included, has induced a decrease in GDP of 0.14014%, which is also low compared to the decrease in emissions.

5. Conclusion

A carbon tax of 50 MAD/ton of CO2 or 75 MAD/ton of CO2 results in an increase in the price of domestic products and consequently a decrease in their demand, i.e. consumption and investment. In addition, the tax through intermediate consumption causes industries to produce and/or export more or less depending on the importance of energy share in intermediary consumption of the branch.

Furthermore, the impact of the tax on domestic price and domestic demand of commodity is reflected in imports. Finally, the decrease in consumption of almost all products results in a negligible decrease in welfare and GDP for the 50 MAD tax compared to the decrease in CO2 emissions, and a small decrease in welfare and GDP for the 75 MAD tax compared to the decrease in CO2 emissions. This means that a tax of 50 MAD/ton of CO2 is a good policy if the goal is to stop the increase in CO2 emissions while having a negligible decrease in GDP and welfare, while a tax of 75 MAD/ton of CO2 is a better option if the goal is to reduce emissions more even if the decrease in GDP and welfare is larger.

Competing interests:
The authors declare none.

References

Bibliography

[1] Decaluwe, Bernard, Andre Lemelin, Helene Maisonnave, et Veronique Robichaud. « PEP-1-1: The PEP standard, computable general equilibrium model, single-country, static version ». *Poverty and Economic Policy (PEP) Research Network*, 2009.

[2] Devarajan, Shantayanan, Delfin S Go, Sherman Robinson, et Karen Thierfelder. « Tax Policy to Reduce Carbon Emissions in a Distorted Economy: Illustrations from a South Africa CGE Model ». *The B.E. Journal of Economic Analysis & Policy* 11, nº 1 (2011). https://doi.org/10.2202/1935-1682.2376.

[3] Ed-daoudi Mohamed Adib, et Kenza Oubejja. « Carbon Tax Effect on the Cereals Market and Electricity Sector in Morocco ». *International Journal of Science and Research (IJSR)* 10, nº 11 (novembre 2021): 983-92. https://doi.org/10.21275/SR211116090247.

[4] Guo, Zhengquan, Xingping Zhang, Yuhua Zheng, et Rao Rao. « Exploring the Impacts of a Carbon Tax on the Chinese Economy Using a CGE Model with a Detailed Disaggregation of Energy Sectors ». *Energy Economics* 45 (1 septembre 2014): 455-62. https://doi.org/10.1016/j.eneco.2014.08.016.

[5] Khastar, Mojtaba, Alireza Aslani, Mehdi Nejati, Kaveh Bekhrad, et Marja Naaranoja. « Evaluation of the Carbon Tax Effects on the Structure of Finnish Industries: A Computable General Equilibrium Analysis ». *Sustainable Energy Technologies and Assessments* 37 (1 février 2020): 100611. https://doi.org/10.1016/j.seta.2019.100611.

[6] Liu, Lirong, Charley Z. Huang, Guohe Huang, Brian Baetz, et Scott M. Pittendrigh. « How a Carbon Tax Will Affect an Emission-Intensive Economy: A Case Study of the Province of Saskatchewan, Canada ». *Energy* 159 (15 septembre 2018): 817-26. https://doi.org/10.1016/j.energy.2018.06.163.

[7] Lu, Chuanyi, Qing Tong, et Xuemei Liu. « The Impacts of Carbon Tax and Complementary Policies on Chinese Economy ». *Energy Policy*, Energy Efficiency Policies and Strategies with regular papers., 38, nº 11 (1 novembre 2010): 7278-85. https://doi.org/10.1016/j.enpol.2010.07.055.

[8] Murray, Brian, et Nicholas Rivers. « British Columbia's revenue-neutral carbon tax: A review of the latest "grand experiment" in environmental policy - ScienceDirect », 2015. https://www.sciencedirect.com/science/article/abs/pii/S0301421515300550.

[9] Nong, Duy. « Development of the Electricity-Environmental Policy CGE Model (GTAP-E-PowerS): A Case of the Carbon Tax in South Africa ». *Energy Policy* 140 (1 mai 2020): 111375. https://doi.org/10.1016/j.enpol.2020.111375.

[10] Oliveira Martins, Joaquim, Jean-Marc Burniaux, John Martin, et Giuseppe Nicoletti. « The Costs of Reducing CO2 Emissions: A Comparison of Carbon Tax Curves with GREEN ». OECD Economics Department Working Paper. OECD Publishing, 1 janvier 1992. https://econpapers.repec.org/paper/oececoaaa/118-en.htm.

[11] Renner, Sebastian, Jann Lay, et Hannes Greve. « Household Welfare and CO2 Emission Impacts of Energy and Carbon Taxes in Mexico ». *Energy Economics* 72 (1 mai 2018): 222-35. https://doi.org/10.1016/j.eneco.2018.04.009.

[12] Wissema, Wiepke, et Rob Dellink. « AGE Analysis of the Impact of a Carbon Energy Tax on the Irish Economy ». *Ecological Economics*, Special Issue on Environmental Accounting: Introducing the System of Integrated Environmental and Economic Accounting 2003, 61, nº 4 (15 mars 2007): 671-83. https://doi.org/10.1016/j.ecolecon.2006.07.034.

[13] Xiao, Kun, Fei Li, Ciwei Dong, Ying Cai, Yanan Li, Penghao Ye, et Jingdong Zhang. « Unraveling Effects of Coal Output Cut Policy on Air Pollution Abatement in China Using a CGE Model ». *Journal of Cleaner Production* 269 (1 octobre 2020): 122369. https://doi.org/10.1016/j.jclepro.2020.122369.

[14] Zhang, Jiekuan, et Yan Zhang. « Carbon Tax, Tourism CO2 Emissions and Economic Welfare ». *Annals of Tourism Research* 69 (1 mars 2018): 18-30. https://doi.org/10.1016/j.annals.2017.12.009.

[15] Zhu, Naiping, Luhuan Qian, Dan Jiang, et Nancy Mbroh. « A Simulation Study of China's Imposing Carbon Tax against American Carbon Tariffs ». *Journal of Cleaner Production* 243 (10 janvier 2020): 118467. https://doi.org/10.1016/j.jclepro.2019.118467.

Webography

[1] https://www.hcp.ma
[2] https://unstats.un.org

Appendices

Nomenclature of products:

Produit	Nomenclature
AGRP	Agriculture, forestry and related services
PAQP	Fishing and aquaculture
GASP	Natural gas
COALP	Coal
C02P	Extraction of metal ores
C03P	Other minerals extraction
IATP	Food industries and tobacco
ITCP	Textile and leather industry
ICPP	Chemical and parachemical industry
IMMP	Mechanical, metallurgical and electrical industry
AINP	Other manufacturing industries excluding oil refining
RPEP	Petroleum refining and other energy products
EAUP	Production and distribution of electricity, water
BTVP	Building and public works
COMP	Trade and repairs
HRSP	Hotels & Restaurants
TRAP	Transports
PTCP	Postal and Telecommunications
AFAP	Financial and insurance activities
IMLP	Real estate, rental and business services
ADMP	General public administration and social security
MNOP	Education, health and social action
OPOP	Other non financial services

List of parameters:

aij(i,j)	Input output coefficient
B_KD(j)	Scale parameter (CES - composite capital)
B_LD(j)	Scale parameter (CES - composite labor)
B_M(i)	Scale parameter (CES - composite commodity)
B_VA(j)	Scale parameter (CES - value added)
B_X(j,i)	Scale parameter (CET - exports and local sales)
B_XT(j)	Scale parameter (CET - total output)
beta_KD(k,j)	Share parameter (CES - composite capital)
beta_LD(l,j)	Share parameter (CES - composite labor)
beta_M(i)	Share parameter (CES - composite commodity)
beta_VA(j)	Share parameter (CES - value added)
beta_X(j,i)	Share parameter (CET - exports and local sales)
beta_XT(j,i)	Share parameter (CET - total output)
eta	Price elasticity of indexed transfers and parameters
frisch(h)	Frisch parameter (LES function)
gamma_GVT(i)	Share of commodity i in total current public expenditures on goods and services
gamma_INV(i)	Share of commodity i in total investment expenditures
gamma_LES(i,h)	Marginal share of commodity i in household h consumption budget
io(j)	Coefficient (Leontief - intermediate consumption)
Kmob	Flag parameter (1 if capital is mobile)
lambda_RK(ag,k)	Share of type k capital income received by agent ag
lambda_TR(ag,agj)	Share parameter (transfer functions)
lambda_WL(h,l)	Share of type l labor income received by type h households
rho_KD(j)	Elasticity parameter (CES - composite capital)
rho_LD(j)	Elasticity parameter (CES - composite labor)
rho_M(i)	Elasticity parameter (CES - composite commodity)
rho_VA(j)	Elasticity parameter (CES - value added)
rho_X(j,i)	Elasticity parameter (CET - exports and local sales)
rho_XT(j)	Elasticity parameter (CET - total output)
sigma_KD(j)	Elasticity (CES - composite capital)
sigma_LD(j)	Elasticity (CES - composite labor)
sigma_M(i)	Elasticity (CES - composite commodity)
sigma_VA(j)	Elasticity (CES - value added)
sigma_X(j,i)	Elasticity (CET - exports and local sales)
sigma_XT(j)	Elasticity (CET - total output)
sigma_XD(i)	Price elasticity of the world demand for exports of product i
sigma_Y(i,h)	Income elasticity of consumption
tmrg(i,ij)	Rate of margin i applied to commodity ij
Tmrg X(i,ij)	Rate of margin i applied to exported commodity i
v(j)	Coefficient (Leontief - value added)

FE(i)	Emission factor of product i

List of variables:

Volume	variables
C(i,h)	Consumption of commodity i by type h households
CG(i)	Public final consumption of commodity i
CI(j)	Total intermediate consumption of industry j
CMIN(i,h)	Minimum consumption of commodity i by type h households
CTH_REAL(h)	Real consumption budget of type h households
DD(i)	Domestic demand for commodity i produced locally
DI(i,j)	Intermediate consumption of commodity i by industry j
DIT(i)	Total intermediate demand for commodity i
DS(j,i)	Supply of commodity i by sector j to the domestic market
EX(j,i)	Quantity of product i exported by sector j
EXD(i)	World demand for exports of product x
G_REAL	Real current government expenditures on goods and services
GDP_BP_REAL	Real GDP at basic prices
GDP_MP_REAL	Real GDP at market prices
GFCF_REAL	Real gross fixed capital formation
IM(i)	Quantity of product i imported
INV(i)	Final demand of commodity i for investment purposes (GFCF)
KD(k,j)	Demand for type k capital by industry j
KDC(j)	Industry j demand for composite capital
KS(k)	Supply of type k capital
LD(l,j)	Demand for type l labor by industry j
LDC(j)	Industry j demand for composite labor
LS(l)	Supply of type l labor
MRGN(i)	Demand for commodity i as a trade or transport margin
Q(i)	Quantity demanded of composite commodity i
VA(j)	Value added of industry j
VSTK(i)	Inventory change of commodity i
XS(j,i)	Industry j production of commodity i
XST(j)	Total aggregate output of industry j

Price	Variables
e	Exchange rate (price of foreign currency in local currency)
P(j,i)	Basic price of industry j's production of commodity i
PC(i)	Purchaser price of composite comodity i (including all taxes and margins)
PCI(j)	Intermediate consumption price index of industry j
PD(i)	Price of local product i sold on the domestic market (including all taxes and margins)
PE(i)	Price received for exported commodity i (excluding export taxes)
PE_FOB(i)	FOB price of exported commodity i (in local currency)
PIXCON	Consumer price index
PIXGDP	GDP deflator
PIXGVT	Public expenditures price index
PIXINV	Investment price index
PL(i)	Price of local product i (excluding all taxes on products)
PM(i)	Price of imported product i (including all taxes and tariffs)
PP(j)	Industry j unit cost including taxes directly related to the use of capital and labor but excluding other taxes on production
PT(j)	Basic price of industry j's output
PVA(j)	Price of industry j value added (including taxes on production directly related to the use of capital and labor)
PWM(i)	World price of imported product i (expressed in foreign currency)
PWX(i)	World price of exported product i (expressed in foreign currency)
R(k,j)	Rental rate of type k capital in industry j
RC(j)	Rental rate of industry j composite capital
RK(k)	Rental rate of type k capital (if capital is mobile)
RTI(k,j)	Rental rate paid by industry j for type k capital including capital taxes
W(l)	Wage rate of type l labor
WC(j)	Wage rate of industry j composite labor
WTI(l,j)	Wage rate paid by industry j for type l labor including payroll taxes

Nominal (value)	Variables
CAB	Current account balance
CTH(h)	Consumption budget of type h households
G	Current government expenditures on goods and services

GDP_BP	GDP at basic prices
GDP_FD	GDP at purchasers' prices from the perspective of final demand
GDP_IB	GDP at market prices (income-based)
GDP_MP	GDP at market prices
GFCF	Gross fixed capital formation
IT	Total investment expenditures
SF(f)	Savings of type f businesses
SG	Government savings
SH(h)	Savings of type h households
SROW	Rest-of-the-world savings
TDF(f)	Income taxes of type f businesses
TDFT	Total government revenue from business income taxes
TDH(h)	Income taxes of type h households
TDHT	Total government revenue from household income taxes
TIC(i)	Government revenue from indirect taxes on product i
TICT	Total government receipts of indirect taxes on commodities
TIK(k,j)	Government revenue from taxes on type k capital used by industry j
TIKT	Total government revenue from taxes on capital
TIM(i)	Government revenue from import duties on product i
TIMT	Total government revenue from import duties
TIP(j)	Government revenue from taxes on industry j production (excluding taxes directly related to the use of capital and labor)
TIPT	Total government revenue from production taxes (excluding taxes directly related to the use of capital and labor)
TIW(l,j)	Government revenue from payroll taxes on type l labor in industry j
TIWT	Total government revenue from payroll taxes
TIX(i)	Government revenue from export taxes on product i
TIXT	Total government revenue from export taxes
TPRCTS	Total government revenue from taxes on products and imports
TPRODN	Total government revenue from other taxes on production
TR(ag,agj)	Transfers from agent agj to agent ag
YDF(f)	Disposable income of type f businesses
YDH(h)	Disposable income of type h households
YF(f)	Total income of type f businesses
YFK(f)	Capital income of type f businesses
YFTR(f)	Transfer income of type f businesses
YG	Total government income
YGK	Government capital income
YGTR	Government transfer income
YH(h)	Total income of type h households
YHK(h)	Capital income of type h households
YHL(h)	Labor income of type h households
YHTR(h)	Transfer income of type h households
YROW	Rest-of-the-world income
TQCO2	Total CO2 emissions
tc(i)	Ad valorem carbon tax
U	Welfare