Article

Efficient costs and policies for emissions control of nitrogen fertilization in Mexican agriculture

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Abstract

From 2000 to 2010, global greenhouse gas emissions not only have not decreased, but have grown to unprecedented levels, thereby increasing the possibility of catastrophic climate change. In 2012, the productive and social activity of humanity produced 52.76 million giga tons of carbon dioxide equivalent (Gt CO_2eq); Mexico issued 663 425 giga tons, 1.3% of the total. Mexican agriculture and livestock contributed 12.3% to the national total. However, the relevance of this problem has been neglected in the investigation of the environmental costs that these emissions imply. The objectives of this research were: 1) to estimate the economic costs of nitrous oxide emissions produced by nitrogen fertilization in Mexican agriculture; and 2) propose, based on them, a fiscal policy for the efficient control of these emissions. The method applied was the general equilibrium of the global economy with emissions. It was concluded that both the use of chemical fertilizers in Mexican agriculture and the agricultural policy are inefficient, so two alternative and efficient policies for the control of these emissions are proposed. The Mexican government must suspend fertilizer subsidies. This would have a negative impact on production, so that efficient emissions control policies must be accompanied by visionary science and technology policies that develop production, keeping emissions within the non-catastrophic levels of climate change.

Keywords: environmental costs, environmental fiscal policy, general equilibrium of the economy.

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Introduction

At the beginning of the industrial revolution, in 1750, the concentration of carbon dioxide (CO_2) in the atmosphere was 280 parts per million (ppm); in 1960 it was 315 and in 2010 it was 380 (Sachs, 2008), 40% above the average values recorded in the last half million years (Lüthi, *et al*., 2008). This means that half of the accumulated emissions of CO_2 between 1750 and 2012 have occurred in the last 42 years, and that this process continues to accelerate. From 1970 to 1999, the emissions of these gases, measured in giga tons of carbon dioxide equivalent (Gt CO_2eq), grew at an annual rate of 1.64%, while from 2000 to 2012 they grew at an average rate of 2.69% (IPCC, 2014). In 2012, the productive and social activity of humanity produced 52.76 million giga tons of carbon dioxide equivalent (Gt CO_2eq):

Table 1. Countries with the highest emissions of carbon dioxide equivalent (CO_2eq) in 2012. (Giga metric tons, Gt CO_2eq).

China	USA	India	Brazil	Russian Fed	Arabia	Japan	Germany	Mexico	G. Brittany	France	Italy	Subtotal	Rest	Total
12 454 710.6	6 343 840.5	3 002 894.9	2 989 418	2 803 398.5	2 577 646.7	1 478 858.9	951 716.7	663 425	585 779.8	499 146.6	482 634	34 833 470.2	17 929 963.1	52 763 433.2

Source: calculations based on data from World Greenhouse Gas Emissions 1970-2012 (Oak Ridge National Laboratory, 2015).

According to Table 1, China produces almost a quarter of global emissions. In addition, China, India, Brazil, the Russian Federation, Arabia and Mexico contribute 46.4% and pollute more than all developed countries as a whole. The reason for this paradoxical fact is that in developing countries environmental regulations are lower and that many industries in more advanced countries have migrated to developing countries.

According to the report of the intergovernmental panel on climate change (IPCC, 2014), between 2000 and 2010 global greenhouse gas (GHG) emissions have not only not decreased, but have grown to unprecedented levels, notwithstanding the growing number of declarations and policies aimed at reducing such emissions. Of the total annual emissions, 52.76 Gt CO_2eq, half, 26.38 Gt, goes to the atmosphere and the other half is absorbed by the 'sinks' of land and oceans. Each additional 7 800 million tons increase the concentration of carbon dioxide in the atmosphere by 2 parts per million (ppm), so in 2012, 3.38 ppm was added to the atmosphere (Sachs, 2008).

According to our calculations, if humanity continued to add 3.38 ppm of CO_2eq to the atmosphere every year, the concentration of these gases would increase from 380 in 2010 to 515.3 in 2050 and 684.4 ppm in the year 2100, which would exceed by far, the critical point tolerable for society, which according to Sachs (2008), is 560 ppm. If the current rates of growth of emissions are maintained, then humanity will reach that critical level sooner than expected, by the year 2050. And if that happens, environmental, ecological, economic and social catastrophes would force us to take measures that are up to the circumstances. For this reason, the international scientific community recommends that all countries reduce, jointly and decisively, emissions of greenhouse gases and compounds, from 52.73 giga tons to 32 by 2050.

In particular for Mexico, this challenge entails social, economic and environmental problems that already affect its population, infrastructure, productive systems and ecosystems (SEMARNAT, 2013). In 2012, Mexico emitted 663 425 giga tons into the atmosphere in units of carbon dioxide equivalent (CO_2eq) of greenhouse gases (GHG). Mexican agriculture and livestock contributed 12.3%. Agricultural emissions are mainly produced by nitrogen fertilization, which emits an important greenhouse gas: nitrous oxide (N_2O), which contributes 50.4% of all emissions from the agricultural sector. González-Estrada and Camacho-Amador (2017) estimated the nitrous oxide emissions produced by nitrogenous chemical fertilization in Mexico and transformed them into units of carbon dioxide equivalent (CO_2eq).

However, the relevance of this problem has been neglected research to estimate the environmental costs of emissions caused by different economic activities and specifically, those generated by different agricultural practices, such as fertilization. Research has focused more on forecasting the impacts of climate change and the vulnerability of economic sectors. For this reason and considering one of the guidelines of the special program for climate change (PECC) in relation to agriculture, which is to achieve efficient use of fertilizers, the objectives of this research were: 1) estimate costs economic or social impacts of nitrous oxide emissions produced by nitrogenous fertilization in mexican agriculture; and 2) propose, based on them, an efficient fiscal-environmental policy for the control of emissions.

Materials and methods

Prices of carbon dioxide and emission permits in general equilibrium

The definition of a price per equivalent ton of carbon dioxide means establishing a market price for policies to reduce greenhouse gas emissions. The definition of a price per equivalent ton of carbon dioxide is a tool or financial mechanism that must reflect the economic, social and ecological costs of climate change. There are three approaches to the corporate definition of coal prices: shadow prices, internal taxes or quotas, and implicit prices (UNFCCC, 2015). The two instruments of the most used emission control policy are: the definition of carbon dioxide prices and the granting of emission permits.

In the last two years the number of instruments for the definition of carbon dioxide prices has almost doubled, since it increased from 20 to 38. Currently, forty countries and twenty cities, which together represent 25% of total emissions to worldwide, they have imposed a price on emissions. The control of emissions by this means represents 12% of global emissions (IBRD, 2015). For example, this carbon dioxide price instrument covers 1 Gt CO_2eq in the US, 0.5 in China and 2 in the European Union. Today, the total value of all instruments of carbon dioxide prices is 50 billion dollars, of which 70% corresponds to the systems of buying and selling of emissions and 30% to carbon taxes. The prices of emissions in equivalent units of carbon dioxide fluctuate between 1 and 130 dollars.

These policy instruments, so variable and chaotic, have not been effective to induce an effective control of the levels of greenhouse gases accumulated in the atmosphere, because the accumulated levels of CO_2eq not only have not been reduced but have grown considerably at dangerous levels. Hence the need to define a method to quantify their efficient levels. The appropriate approach is, obviously, that of general equilibrium, since GHG emissions have effects that are not only general within each country but also have global or planetary consequences. However, global carbon markets (CO_2eq) are incomplete, so the general equilibrium allocations are far from efficient. Consequently, the creation of markets in which pollution permits are offered and demanded can result in optimal assignments in the Pareto sense, only if the allocations obtained there are feasible and if economic agents that produce externalities should pay the corresponding cost to the negative economic consequences of their decisions and productive activities (González-Estrada, 2003 and 2004).

The general equilibrium of the economy with emission permits

The creation and organization of international markets for emission permits is one of the policy measures for the control of greenhouse gas emissions that has received more attention from experts (Tientenberg, 1992), due to its advantages, the most important of which is its ability to be instrumented and carried out with a minimum bureaucratic apparatus and with low transaction costs (Larsen and Shah, 1994). In addition, they are the most promising instruments of environmental policy in current conditions (Grubb, 1989 and 1990), since they are also flexible, effective and efficient to reduce levels of CO_2Eq in the atmosphere.

The general equilibrium model proposed here is an adaptation of the model of a global economy with emissions of greenhouse gases and emission permits, initially built by Uzawa (2010). Let θ_φ be the annual emission of greenhouse gases (GHG) measured in units of carbon dioxide equivalent, CO_2eq, in the country φ=1, 2, …, n and be θ the total emissions of those gases a global level: $\theta= \theta_1 + \theta_2 + \cdots + \theta_n$. For each country, its emissions: θ_φ, plus those of the rest of the world: θ, add the total emission: Θ. That is: $\Theta= \theta + \theta_\varphi$. The set of production possibilities of each country φ is: T_φ, $\forall\ \varphi$= 1, 2, …, n. In each country there are L productive factors: $k_\varphi=(k_{\varphi 1}, k_{\varphi 2}, \dots, k_{\varphi L})$, which have the following properties: $k_\varphi \geq 0$; that is: $k_{\varphi l} \geq 0\ \forall$ l= 1, 2, …, L and $k_{\varphi l} > 0$, for some l. In this economy there are k goods: j=1, 2, …, k. The minimum number of factors of production required to produce the vector of goods or products in each country is: $x_\varphi= (x_{\varphi 1}, x_{\varphi 2}, \dots, x_{\varphi L})$. The national income of the country φ, whose emissions are θ_φ, is: $y_\varphi= f_\varphi(k_\varphi, \theta_\varphi)$. The technologies exhibit constant returns to scale and the set of production possibilities for this economy, T_φ, is closed and convex for the vectors $(k_\varphi, \theta_\varphi) \in R^{1+n+c}$. There are *k* goods and the price vector is: $p=(p_1, p_2, \dots, p_k) \in R_+^k$ (Uzawa, 1991 and 1992).

The function that represents the partial orderings for the consumption c_φ and for the total global amount, at planetary level, of the annual emissions of greenhouse gases, θ, expressed in equivalent units of carbon dioxide, CO_2eq, where: $\theta= \theta_1 + \theta_2 + \cdots + \theta_n$, is the function $u_\varphi= u(c_\varphi,\theta)$ (Uzawa, 1991 and 1992).

Let $\psi(\theta)$ be the degree to which the country's family units φ are affected by emissions θ. Obviously, $\psi(\theta)$ can be called global warming index, identical for all countries, and, in addition: $\psi(\theta)> 0$, $\psi'(\theta)< 0$; $\psi''(\theta)< 0$, $\forall\ \theta\in(0,\hat{\theta})$, where θ is a critical level of emissions and means that if $\hat{\theta}$ continues to grow beyond $\hat{\theta}$ irreversible damage will occur to humanity. Uzawa (1991 and 1992a) postulated the following index of global warming: $\psi(\theta)= (\hat{\theta}- \theta)^\beta$, $\theta\in(0,\hat{\theta})\wedge\beta\in(0,1)$. The marginal rate of change of the environmental impact index due to a marginal increase in emissions of CO_2 equivalent is:

$$r_\varphi(\theta)=\frac{\psi'_\varphi(\theta)}{\psi_\varphi(\theta)}, \forall\ \varphi= 1, 2, \ldots, n$$

This marginal rate is also known as the coefficient of impact of global warming. The vector of the tax rates on emissions is: $\tau_\varphi= (\tau_{\varphi 1}, \tau_{\varphi 2}, \ldots, \tau_{\varphi k})$ and the cost vector of the production factors is: $\omega_\varphi=(\omega_{\varphi 1}, \ldots, \omega_{\varphi L})$.

How should the general equilibrium of this economy be defined with emissions of greenhouse gases and taxes? What are the necessary and sufficient conditions for the existence of a general equilibrium with efficient assignments of pollution permits?

In order to answer these questions, it is assumed that there is an international market for emission permits, in which countries buy and sell permits to issue CO_2Eq. Let θ_φ be the amount of CO_2Eq issued by the country $\varphi= 1, 2, \ldots, n$ and let b_φ, the amount of the emission permits for that country. If $\theta_\varphi> b_\varphi$, the country would have to buy $(\theta_\varphi - b_\varphi)$ emission permits, but if $\theta_\varphi >b_\varphi$, then it could sell $(b_\varphi - \theta_\varphi)$ permits. From an institutional point of view, the central problem is how to reach an agreement regarding the definition of the initial quantity of permits offered (Rose and Stevens, 1993; Bertram, 1992; Larson and Shah, 1992; 1994). It is assumed that both θ and b were already determined and that, as already said: $b= \sum_{\varphi=1}^{n} b_\varphi$, $\theta=\sum_{\varphi=1}^{n} \theta_\varphi$. The condition of the balance of payments for the country φ is: $pc_\varphi=px_\varphi-q(\theta_\varphi-b_\varphi)$,where $p=(p_1, p_2, \ldots, p_k)$ is the price vector of the k goods produced and q is the price of the emission permits in the international market. In addition, c_φ is the consumption vector and x_φ is the vector of goods produced in the country $\varphi=1, 2, \ldots, n$.

The general equilibrium of the world economy with emission permits is the matrix of production, consumption and price allocations: $(p^*, q^*, \omega^*_\varphi, p^*_{em}; x^*_\varphi, c^*_\varphi, k^*_\varphi, \theta^*_\varphi)$, such that: a) in each country, companies maximize profits $\pi_\varphi= p.f_\varphi(k_\varphi, \theta_\varphi)- w_\varphi k_\varphi - q\theta_\varphi$; b) solve Max's problems $(u_\varphi(c_\varphi,\theta)=\psi(\theta)u_\varphi(c_\varphi))$, subject to $p.c_\varphi= px_\varphi - q(\theta_\varphi - b_\varphi)$; c) globally, goods markets are balanced: $\sum_{\varphi=1}^{n} c_\varphi = \sum_{\varphi=1}^{n} x_\varphi$, and finally, d) the sum of the emissions of CO_2Eq of all countries is equal to the authorized amount of emission permits: $\Sigma\sum_{\varphi=1}^{n} \theta_\varphi = \theta = \sum_{\varphi=1}^{n} b_\varphi = b$. The general equilibrium conditions, necessary and sufficient, given concavity conditions, are:

$$p\frac{\partial f_\varphi}{\partial k_\varphi} - w = 0 \quad 1) \qquad \wedge \ -p\frac{\partial f_\varphi}{\partial \theta_\varphi} - q = 0 \quad 2)$$

$$p\cdot f_\varphi(k_\varphi, \theta_\varphi) - wk_\varphi - q\theta_\varphi = 0 \quad 3)$$

$$\alpha_\varphi \psi(\theta) u'_\varphi(c_\varphi) - p = 0 \quad 4)$$

$$\psi'(\theta) u_\varphi(c_\varphi) - \lambda_\varphi q = 0 \quad 5)$$

$$p\cdot c_\varphi = p\cdot x_\varphi - q(\theta_\varphi - b_\varphi) \quad 6)$$

$$\sum_{\varphi=1}^{n} x_\varphi = \sum_{\varphi=1}^{n} c_\varphi = 0 \ \wedge \ \sum_{\varphi=1}^{n} \theta_\varphi = \sum_{\varphi=1}^{n} b_\varphi \quad (7\text{-}8)$$

If they are multiplied (1) and (2) respectively by k and θ_φ if they are summed and if Eüler's theorem is applied, we get:

$$wk + q\,\theta_\varphi = p\left(\frac{\partial f_\varphi}{\partial k_\varphi} k_\varphi + \frac{\partial f_\varphi}{\partial \theta_\varphi}\theta_\varphi\right) = pf_\varphi(k_\varphi \theta_\varphi) = y_\varphi$$

That is, $y_\varphi = wk + q\,\theta_\varphi = p\cdot c_\varphi$. This means that the national income or the total value of production is equal to the sum of the payments to the factors of production: capital and labor force. Since $q\theta_\varphi$ is the value of the emission allowance assignment at market prices, then: $yy_\varphi = wk + q\,b_\varphi = (p\,x_\varphi - q\,\theta_\varphi) + q\,b_\varphi = px_\varphi - q(\theta_\varphi - b_\varphi) \equiv p\cdot c_\varphi$. Clearly: $p\cdot x_\varphi - q\,\theta_\varphi \equiv wk$. Note also, that if both sides of condition (4) are multiplied by c_φ and the Eüler Theorem is applied, we get:

$$\alpha_\varphi \psi(\theta) u_\varphi(c_\varphi) = y_\varphi \ \ (p\cdot c_\varphi = y_\varphi) \quad (8)$$

The general equilibrium requires that: a) the vectors (p^*, q^*) meet the conditions (1)-(8); b) in each country the taxes on the emissions are equal to the market price of the same, q^*, and c) the balance of payments is balanced, defined as: $pc_\varphi = px_\varphi - q(\theta_\varphi - b_\varphi)$. The general equilibrium of the country φ for φ = 1, 2, ..., n, characterized by conditions (1) - (8) will be efficient in the Pareto sense, if $\theta = b$ and, of course, if: $\theta_\varphi = b_\varphi, \forall\ \varphi = 1, 2, \ldots, n$. Condition (4) implies that:

$$\alpha_\varphi \psi(\theta) u'_\varphi(c_\varphi) = p \quad 9)$$

where: $\alpha_{\varphi}= \left(1/\lambda_{\varphi}\right)> 0, \forall_{\varphi}$ y λ_{φ} is the opportunity cost of money or the marginal utility of income. Finally, from the general equilibrium conditions, from the definition equation: $y= p\cdot c$ and from Eüler's theorem, we obtain: $r_{\varphi}(\theta)=\left(\tau_{\varphi}(\theta)/y_{\varphi}\right)$, so that:

$$\tau_{\varphi}(\theta)= \hat{q}= r_{\varphi}(\theta)y_{\varphi} \qquad 10)$$

Therefore, the tax rate that the country φ must pay for its greenhouse gas emissions is: $\tau^{*}_{\varphi}(\theta)= r_{\varphi}(\theta)y_{\varphi}$, where $\tau^{*}_{\varphi}(\theta)$ is the tax on emissions of CO_2eq in the country φ, $r_{\varphi}(\theta)$ is the coefficient of environmental impact and y_{φ} is the national income of the country φ. Given that $p\cdot c= p\cdot x= y$, then the optimal tax corresponding to sector j in country φ is given by the following expression: $\tau^{*}_{\varphi j}(\theta)=r_{\varphi j}(\theta)y_{\varphi j}$, where $r_{\varphi j}(\theta)$ is the tax rate that sector j of the country φ must pay for its emissions of greenhouse gases and $y_{\varphi j}$ is the national income produced by sector j in the country φ.

Results

The cost of nitrogenous fertilization emissions in Mexican agriculture

Climate change is an inexorable reality, whose effects, at best, can only be mitigated. According to Sachs (2008), the most severe and catastrophic impacts could be avoided if the global temperature of the atmosphere increases less than 2 degrees Celsius in relation to the average temperature prevailing in the reference period: the beginnings of the industrial revolution to mid eighteenth century. To achieve this, it is necessary to reduce the 52.76 giga-tons of CO_2eq produced in 2012 to only 32 by the year 2050. At present, the global costs associated with mitigation and adaptation to climate change add up to an amount between 385 billion dollars per year; the investments that are expected to be made by the year 2030 should be of 400 billion dollars per year and by 2050, of 2 billion dollars per year (IBRD, 2015). Today, coal prices are fragmented by countries and, within them, by sectors of the economy (IBRD, 2015). In addition, they are fixed in a very wide range: from 1 to 130 dollars. It is obvious that those prices are far from being efficient, socially speaking. This dispersion reflects the fact that the richest countries transfer the most polluting activities to the poorest countries, who, in order to attract investments, lower environmental standards. It also explains why the ten largest developing economies pollute more than the ten most developed and richest countries.

Uzawa (2010) shows that if $b^{*}= \theta$; that is, if emission permits equal the total amount of emissions, then the general equilibrium solution with emission permits is equal to the general equilibrium with emission taxes, so the total planetary cost of emissions of CO_2eq is: $q^{*}=r(\theta)y$. Consequently, the cost of a ton of CO_2eq is:

$$\pi^{*}=\frac{q^{*}}{b^{*}}=\frac{q^{*}}{\theta}=\frac{r(\theta)y}{\theta}=\frac{53\times10^{12}\text{ dollars}}{52.76\times10^{6}\text{ Gt of }CO_2\text{eq}}\cong 100\text{ dollars t}^{-1}\text{ of }CO_2\text{eq}$$

This estimator is consistent with the results obtained by Golosov *et al*. (2014), who, with a stochastic general equilibrium dynamic model, estimated an efficient cost of emissions of 56.9 dollars per ton if the discount rate were 0.5% and 496 dollars if that rate was 1.5%. If you want to avoid that the global temperature of the atmosphere increases less than 2 degrees Celsius in relation to the average temperature prevailing in the mid-eighteenth century and that the economic, social and environmental effects of climate change reach catastrophic and unavoidable levels by the year 2050 , the price that each emission permit must have is $100.00 dollars per ton of CO_2eq. Something similar is reported by the International Bank for Reconstruction and Development (IBRD, 2015). This is the cost to maintain the production of humanity within the set of non-catastrophic feasibility. Consequently, the costs of the emissions produced by chemical fertilization in Mexican agriculture are the following.

Efficient emission control policies

The nitrous oxide emissions produced by the application of chemical-nitrogen fertilizers represent 50.4% of the emissions of the agricultural sector (SEMARNAT, 2013). According to Table 2, it is estimated that in 2014 emissions from this sector were 11 617 million tons of CO_2eq, which represent a cost of 19 982.2 million pesos in 2017. In that year, the Agricultural GDP was 280 billion pesos, so the ad valorem tax on emissions of greenhouse gases should equal 7.14%. In order to better understand this result as part of a whole, González-Estrada *et al*. (2011) cite that in 2004 the total costs for depletion and environmental degradation (CTADA) in Mexico represented 9.2% of GDP; that is, 712 344 million pesos, an amount that reflects the amount of natural capital appropriated as surplus or extraordinary profits by the economic agents benefited without paying anything in return.

Table 2. Cost of emissions of CO_2eq produced by chemical fertilization in Mexican agriculture.

Year	Apparent consumption of fertilizers with N (t)	Total emissions (t)	Total cost (pesos of 2017)
2000	1 342 000	8 689 886	14 946.6
2001	1 374 100	7 456 403	12 825
2002	1 176 400	7 939 211	13 655.4
2003	886 124	7 700 389	13 244.7
2004	907 137	7 631 970	13 127
2005	915 801	6 770 920	11 646
2006	1 057 564	7 793 336	13 404.5
2007	1 141 863	7 726 208	13 289.1
2008	939 477	8 604 039	14 798.9
2009	856 546	8 391 036	14 432.6
2010	823 145	8 662 131	14 898.9
2011	837 502	8 869 325	15 255.2
2012	989 000	7 593 242	13 060.4
2013	1 001 838	5 719 614	9 837.7
2014	1 097 914	5 855 245	10 071

Source: calculations based on the total emissions of CO_2eq produced by chemical fertilization in Mexican agriculture, estimated by González-Estrada and Camacho-Amador (2017).

Gonzalez-Estrada *et al*. (2011) estimated the efficient environmental tax for each economic sector in Mexico. The agricultural, forestry and fishing sector produced an environmental degradation equivalent to 49 226 million pesos, so the efficient environmental tax that should be paid is 13.15%. This ad valorem tax of 7.14%, obtained here, although efficient in terms of Pareto, would be ineffective due to the high levels of tax evasion and, in addition, would have high transaction costs, since its implementation would be onerous.

With the help of models of general dynamic equilibrium of the world economy it was estimated that the efficient cost of a permit to issue a ton of C_2Oeq should be $ 100.0 dollars (IBRD, 2015), and that this is the efficient price, in Pareto terms, of an emission permit for a ton of $C_2O\ eq$. According to Uzawa (2010), if b= θ, the general equilibrium with emission permits corresponds to the differential equilibrium with taxes on emissions.

Therefore, an equivalent and equally efficient policy would be to establish a Pigouvian tax on chemical fertilizers, according to the relative nitrogen content, using the same method followed to obtain the total cost of emissions in the Table 3 and in accordance with the procedure proposed by González-Estrada (2003 and 2004).

Table 3. Emissions and efficient tax for one ton of each type of fertilizer.

Fertilizer (1 t)	Content (t of N)	Emissions CO_2eq		Total emissions CO_2eq		Tax (pesos kg^{-1})
		Direct	Indirect	(Gg)	(t)	
Nitrogenated						
Urea	0.46	0.00224086	0.00072828	0.00296914	2.9691	5.11
Ammonium nitrate	0.335	0.00163193	0.00053038	0.00216231	2.1623	3.72
Ammonium sulphate	0.205	0.00099864	0.00032456	0.0013232	1.3232	2.28
Ammonium phosphate	0.21	0.001023	0.00033248	0.00135548	1.3555	2.33
Phosphates						
Simple superphosphate	0.195	0.00094993	0.00030873	0.00125866	1.2587	2.16
Concentrated superphosphate	0.46	0.00224086	0.00072828	0.00296914	2.9691	5.11
Ammonium phosphate	0.5	0.00243571	0.00079161	0.00322732	3.2273	5.55
Potash						
Potassium sulfate	0.5	0.00243571	0.00079161	0.00322732	3.2273	5.55
Potassium chloride, Sup. 45%	0.53	0.00258186	0.0008391	0.00342096	3.421	5.88

Source: calculations with the method followed by Gonzalez-Estrada and Camacho-Amador (2017).

Discussion

Irrationality of the use of fertilizers in Mexican agriculture

Chemical fertilization in Mexican agriculture is inefficient economically and socially, in the sense that they define efficiency MasColell, *et al*. (1995); Varian (1992); Jehle and Reny (2011), because neither the producers nor the authorities nor society take into account the costs of nitrous oxide emissions that fertilizer applications have. Moreover, in the calculation of the optimal-economic doses of fertilization, emissions costs have not been taken into account and, therefore, fertilization practices in Mexico are not economically or socially efficient either.

The current policy of fertilizer subsidies, which promotes greater use than optimal-economic doses and also does not take into account the costs of nitrogen-containing chemical fertilizer emissions, is also inefficient, firstly, because subsidies are inefficient in their own right and, secondly, because they encourage excessive use of nitrogen fertilizers and, therefore, stimulate emissions of nitrous oxide, which has a heating potential 310 times greater than that of carbon dioxide, as it is reported by SEMARNAT (2013).

Conclusions

The use of chemical fertilizers in Mexican agriculture is inefficient and, therefore, irrational, and so is the current policy of fertilizer subsidies, since it encourages irrational and inefficient use from the economic, social and environmental points of view. The optimal-economic doses of fertilization must be redefined taking into account current practices, the prices of products and fertilizers, as well as the costs of emissions.

The government of Mexico must stop subsidizing the indiscriminate use of fertilizers and apply an optimal and efficient policy to control emissions in agriculture, in the economy in general and in Mexican society as a whole. This policy will imply significant decreases in production, which is why it must be accompanied by visionary science and technology policies (González-Estrada, 2003) that promote the generation of innovations and production techniques for the development of the economy, keeping emissions within of the non-catastrophic levels of climate change.

Cited literature

Bertram, G. 1992. Tradable emission permits and the control of greenhouse gases. J. Development Studies. 28(3):423-446.

DOF. 2013. Diario Oficial de la Federación. Programa especial de cambio climático 2014-2018. Lunes 28 de abril, segunda sección vespertina. México, DF. 96 p.

Golosov, M.; Hassler, J.; Krusell, P. and Tsyvinski, A. 2014. Optimal taxes on fossil fuel in general equilibrium. Econometrica. 82(1):41-88.

González, E. A. 2003. Economía de la contaminación en la teoría del equilibrio general competitivo: Parte I. Reformulación del modelo y efectos Stolper-Samuelson. Agrociencia 37(1):45-55.

González, E. A. 2004. Economía de la contaminación en la teoría del equilibrio general competitivo: Parte II. efectos Rybcszynski y políticas eficientes y óptimas de control. Agrociencia 38(3):313-324.

González, E. A. y Camacho, A. M. 2017. Emisión de gases de efecto invernadero de la fertilización nitrogenada en México. Rev. Mex. Cienc. Agríc. 8(8):1733-1745.

González, E. A.; Camacho, A. M. y Sangermán, J. D. M. 2011. Incorporación de cuentas ecológicas y servicios ambientales en las matrices de contabilidad social. Rev. Mex. Cienc. Agríc. 2(5):715-731.

Grubb, M. J. 1989. Greenhouse effects: negotiating targets. Royal Institute of International Affairs. London. 12 p.

Grubb, M. J. 1990. International marketable emission permits: key issues. IPCC/OECD Workshop on financial and economic measures as a response to climate change. Paris. 25 p.

IBRD. 2015. International Bank for Reconstruction and Development. State and trends of carbon pricing. The World Bank. Washington, DC. 85 p.

IPCC. 2014. Intergovernmental Panel on Climate Change. Greenhouse gas emissions accelerate despite reduction efforts. IPCC press released on April 13, 2014. Berlin. 3 p.

Jehle, G. A. and Reny, P. J. 2011. Advanced microeconomic theory. Prentice Hall. NY. 656 p.

Larsen, B. and Shah, A. 1994. Combating greenhouse effect. Finance & Development. 46(4):842-856.

Lüthi, D.; LeFloch, M.; Bereiter, B.; Blunier, T.; Barnola, J. M.; Siegenthaler, U.; Raynaud, D.; Jouzel, J.; Fischer, H.; Kawamura, K. and Stocker, T. F. 2008. High-resolution carbon dioxide concentration record 650 000-800 000 years before present. Nature, May 15. 453(15):379-382.

MasColell, A.; Whinston, M. D. and Green, J. R. 1995. Microeconomic theory. Oxford University Press. Cambridge, England. 981p.

Oak Ridge National Laboratory. 2015. Global, regional, and national fossil-fuel CO_2 emissions, 1970-2012. Carbon Dioxide Information Analysis Center, Environmental Sciences Division. U.S. Department of Energy. Oak Ridge, Tennessee. United States. (Excel data base). http://cdiac.ornl.gov/CO2_emission/timeseries/global.

Rose, A. and Steven, B. 1993. The efficiency and equity of marketable permits for CO_2 emissions. Resources and Energy Economics. 15(1):117-146.

Sachs, J. 2008. Common wealth: economics for a crowded planet. The Penguin Press. New York. 400 p.

SEMARNAT. 2013. Secretaría de Medio Ambiente y Recursos Naturales. Inventario nacional de emisiones de gases efecto invernadero 1990-2010. México DF. 384 p.

SEMARNAT-INE. 2006. Secretaría de Medio Ambiente y Recursos Naturales e Instituto Nacional de Ecología. Inventario nacional de emisiones de gases de efecto invernadero, 1990-2002. México, DF. 32 p.

Tietenberg, T. 1992. Relevant evidence with tradable entitlements. In: Dornbusch, R. and Poterba, J. M. (Eds.). Combating global warming: Study on a global system of tradable carbon emission entitlements. MIT Press. Cambridge, MA. 267 p.

UNFCCC. 2015. United Nations Framework Convention on Climate Change Executive guide for carbon pricing leadership: a caring for climate report. UN Global Compact, the secretariat of the UN Framework Convention on Climate Change (UNFCCC), United Nations Environment Program (UNEP), World Resources Institute (WRI) UN Global Compact, the secretariat of the UN Framework Convention on Climate Change. New York. 34 p.

Uzawa, H. 1991. Global warming initiatives: the pacific rim. *In*: Dornbusch, R. and Poterba, J. M. (Eds.). Global warming: economic policy responses. MIT Press. Cambridge, MA. 411 p.

Uzawa, H. 1992. Imputed prices of greenhouse gases and land forests. Renewable energy 3(4-5):499-511.

Uzawa, H. 2010. Global warming, carbon taxes, and international fund for atmospheric stabilization. Initiative for policy dialogue’s. Climate Task Force Meeting, University of Manchester. Manchester, UK. 31 p.

Varian, H. R. 1992. Microeconomic Analysis. W.W. Norton & Company. New York. 563 p.