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Abstract

The responsibility for, and consequences of, greenhouse gas emissions are shared by all countries, but only a few are willing to tax emissions. The paper argues that the reactions of the abstaining countries are crucial for assessing the effectiveness of the tax. The paper analyzes an interaction between a tax-collecting and investing coalition of rich countries, abstaining rich countries and poor countries. The non-coalition countries might have loss of reputation and guilt and overstate the tax's emission-moderating effect. As long as these three types of countries react to their counterparts' emissions, taxing emissions does not necessarily reduce the global emissions. (*JEL* Q52)

Keywords: Emission Tax; Abstinence; Understating Expectations; Guilt; Global Emissions

1. Introduction

Price incentives for dealing with greenhouse gas emissions have been argued to be efficient and leading to outcomes with greater welfare than quantity controls (Pizer, 2002; Hoel and Karp, 2002; Newell and Pizer, 2003; Fischer and Newell, 2008). The advocates of emission tax expect the tax to reduce greenhouse gas emissions by increasing efficiency in carbon-fuels' use and encouraging and financing the development and adoption of cleaner sources of energies and technologies. While responsibility for, and consequences of, greenhouse gas emissions are shared by all countries, only a few are willing to tax emissions. The paper argues that the reactions of the unwilling countries to the expected emissions of the willing countries are crucial for assessing the effectiveness of this price incentive.

The analysis leading to the said conclusion is based on a framework that allows an emission-tax-charging coalition of environmentally concerned rich countries to be formed. The coalition taxes members' emissions and generates a positive common-pool externality for members by concertedly investing the tax revenues in improving the use of carbon-fuels and developing and adopting low-emission energy sources and technologies. The abstaining less concerned rich countries incur international reputation and political loss for per capita emissions beyond the coalition's level. Poor countries do not incur such loss due to their low per capita emissions or, otherwise, forgiven due to their low per capita income. The positive common-pool externality and the international reputation and political loss increase the propensity of the environmentally more concerned rich countries to stay in the coalition.

With this framework in mind, the equilibrium per capita emissions of the coalition-countries, abstaining rich countries and poor countries are derived. The computation of the equilibrium emissions takes into account that some of the expectations of the three types of countries about each other's emissions can be understated due to a possible excessive impression created by the coalition's environmental initiatives. The computation also takes into account a possible guilt effect on the abstaining countries' concerns for the environment.

The computed equilibrium reveals that as long as the three types of countries react to their counterparts' emissions, taxing emissions and investing the tax revenues in development and adoption of cleaner energy sources and technologies would not necessarily reduce the global emissions, nor the coalition's emissions. This conclusion also holds under accurate expectations and absence of guilt in the abstaining countries. The analysis of the equilibrium identifies the conditions under which the unilateral implementation of the emission tax by the coalition decreases the coalition's and global emissions.

2. Framework

Suppose that the world has N_r rich countries divided into two distinct groups by their degree of concern about the state of the world's environment. Those with the higher degree of concern (denoted by subscript rc), N_{rc} in number, form an emission-tax collecting and investing coalition. The other $N_r - N_{rc}$ rich countries with the lower degree of concern (denoted by subscript ra), abstain. The population of each of the coalition countries is P_{rc} and the population of each of the abstaining rich countries is P_{ra}. The poor countries (denoted by subscript p) are N_p in number. They have the same size of population, P_p, and the same degree of concern about the state of the world's environment. The three types of countries produce the same composite good, but with different technologies and levels of emission per unit.

With q_p indicating the emissions released by the production process of the representative resident of the poor countries and $\alpha > 0$ the ratio of his output to emissions, the per capita output and also (with income-tax revenues being redistributed) disposable income in the poor countries is:

$$y_p^d = \alpha q_p . \tag{1}$$

Before the formation of the emission-tax collecting and investing coalition, all the N_r rich countries have shared a technology that was cleaner than that of the poor countries. This technology prevails in the abstaining rich countries. With q_{ra} indicating the emissions released by the production process of the representative resident of the abstaining rich countries and $\eta > 0$ the difference in the output-emission ratio between the abstaining rich countries and the poor countries, the per capita output and also disposable income in the abstaining rich countries is:

$$y_{ra}^d = (\alpha + \eta) q_{ra} . \tag{2}$$

With q_{rc} indicating the emissions released by the production process of the representative resident of the coalition's rich countries, $\tau > 0$ the emission-tax rate on domestic emissions set by the coalition, and $\beta > 0$ the marginal return on the aggregate emission-tax revenues $(\tau q_{rc} N_{rc} P_{rc})$ invested concertedly by the coalition in development and adoption of cleaner energy sources and technologies, the per capita disposable income in the coalition countries is:

$$y_{rc}^{d} = [(\alpha + \eta) + \beta(\tau N_{rc} P_{rc} q_{rc}) - \tau] q_{rc} \,. \tag{3}$$

The term $\beta(\tau N_{rc} P_{rc} q_{rc})$ displays a positive common-pool externality. In addition to a greater concern about the environment and a potential international reputation and political loss, access to the cleaner energy sources and technologies developed by the concerted investment of the aggregate emission-tax revenues provides an incentive for each of the N_{rc} coalition countries to cooperate.

With E_0 denoting the initial state of the global environment, $g_e > 0$ the global environment's natural regeneration rate and $\delta > 0$ the adverse effect of deviation from zero emissions on the global environment (footprint coefficient), the change in the global environment is:

$$\Delta E = g_e E_0 - \delta [q_p N_p P_p + q_{rc} N_{rc} P_{rc} + q_{ra} (N_r - N_{rc}) P_{ra}]^2 \,. \tag{4}$$

Each type of country, $i = p, ra, rc$, gains utility from its per capita disposable income, y_i^d, at a rate $\gamma_i > 0$, which represents the (constant, for simplicity) marginal utility from disposable income. It also gains utility from environmental improvement ($\Delta E > 0$) and loses utility from environmental deterioration ($\Delta E < 0$) at a rate $\phi_i > 0$ that reflects its degree of concern about changes in the environment. Recalling the aforementioned concern-differential between the two types of rich countries, $\phi_{rc} > \phi_{ra}$. The 'environmental Kuznets curve hypothesis' (Selden and Song, 1994; Grossman and Krueger, 1995) and the 'affluence hypothesis' (Diekmann and Franzen, 1999; Franzen, 2003) suggest that $\phi_{ra} > \phi_p$. The per capita utility in an abstaining rich country is further diminished by international reputation and political loss from exceeding the coalition's per capita emission. This loss is intensified by the exceptionality of the rich country's abstinence and by the power of the coalition, which are reflected by $N_{rc} P_{rc} / [(N_r - N_{rc}) P_{ra}]$. With the scalar ψ (positive and proportional to $N_{rc} P_{rc} / [(N_r - N_{rc}) P_{ra}]$ when $q_{ra} - q_{rc} > 0$ and zero otherwise) denoting the international reputation and political loss coefficient:

$$u_i = \begin{cases} \gamma_i y_i^d + \phi_i \Delta E & \text{for } i = p, rc \\ \gamma_i y_i^d + \phi_i \Delta E - \psi (q_{ra} - q_{rc})^2 & \text{for } i = ra. \end{cases} \tag{5}$$

In view of (1)-(5), the utilities of the representative agents of the three types of countries are:

$$u_p = \gamma_p \alpha q_p + \phi_p \{ g_e E_0 - \delta [q_p N_p P_p + q_{rc} N_{rc} P_{rc} + q_{ra} (N_r - N_{rc}) P_{ra}]^2 \} \tag{6}$$

$$u_{rc} = \gamma_{rc}[(\alpha+\eta)+\beta(\tau N_{rc}P_{rc}q_{rc})-\tau]q_{rc} + \phi_{rc}\{g_e E_0 - \delta[q_p N_p P_p + q_{rc}N_{rc}P_{rc} + q_{ra}(N_r - N_{rc})P_{ra}]^2\} \quad (7)$$

$$u_{ra} = \gamma_{ra}(\alpha+\eta)q_{ra} + \phi_{ra}\{g_e E_0 - \delta[q_p N_p P_p + q_{rc}N_{rc}P_{rc} + q_{ra}(N_r - N_{rc})P_{ra}]^2\} - \psi(q_{ra}-q_{rc})^2. \quad (8)$$

In each of the three types of countries, per capita emission is set at a level that maximizes the representative agent's utility, given the expectations about the foreign counterparts' emissions.

3. Reactions to counterparts' emissions

The reaction function of the utility-maximizing representative agent living in a poor country to the expected emissions (denoted by the superscript e/p) of the agents living in the coalition's rich countries and the abstaining rich countries is:

$$q_p = \left(\frac{\gamma_p \alpha}{2\phi_p \delta (N_p P_p)^2}\right) - \left(\frac{N_{rc}P_{rc}}{N_p P_p}\right) q_{rc}^{e/p} - \left(\frac{(N_r - N_{rc})P_{ra}}{N_p P_p}\right) q_{ra}^{e/p}. \quad (9)$$

The representative agent of a poor country reduces (increases) his emissions when a rise (decline) in his richer counterparts' emissions is expected, proportionally to their relative population size. The first term on the right-hand side of equation (9) indicates the poor countries' optimal per capita emission in the absence of emissions from other sources.

The reaction function of the utility-maximizing representative agent living in a coalition country to the expected emissions (denoted by the superscript e/rc) of the agents living in the non-coalition rich countries and the poor countries is:

$$q_{rc} = \left(\frac{\gamma_{rc}(\alpha+\eta-\tau)}{2[\phi_{rc}\delta N_{rc}P_{rc} - \beta\tau]N_{rc}P_{rc}}\right) - \left(\frac{\phi_{rc}\delta N_p P_p}{\phi_{rc}\delta N_{rc}P_{rc} - \beta\tau}\right) q_p^{e/rc} - \left(\frac{\phi_{rc}\delta(N_r - N_{rc})P_{ra}}{\phi_{rc}\delta N_{rc}P_{rc} - \beta\tau}\right) q_{ra}^{e/rc}. \quad (10)$$

Noting that by the second-order condition for maximum $\phi_{rc}\delta N_{rc}P_{rc} - \beta\tau > 0$, the representative agent of a coalition country reduces (increases) his emissions when a rise (decline) in his poor and abstaining-rich counterparts' emissions is expected. His reaction is intensified by his counterparts' relative population size and by the return on the investment of the emission-tax in developing and adopting cleaner energy sources and technologies. The first term on the right-hand side of equation (10) indicates the coalition's optimal per capita emission in the absence of emissions from the abstaining countries.

The reaction function of an agent living in an abstaining rich country to the expected emissions (denoted by the superscript e/ra) of the agents living in the coalition's rich countries and poor countries is:

$$q_{ra} = \frac{0.5\gamma_{ra}(\alpha+\eta)}{[\phi_{ra}\delta(N_r - N_{rc})^2 P_{ra}{}^2 + \psi]} - \frac{\phi_{ra}\delta N_p P_p (N_r - N_{rc}) P_r}{[\phi_{ra}\delta(N_r - N_{rc})^2 P_{ra}{}^2 + \psi]} q_p^{e/ra} - \frac{[\phi_{ra}\delta N_{rc} P_{rc}(N_r - N_{rc}) P_{ra} - \psi]}{[\phi_{ra}\delta(N_r - N_{rc})^2 P_{ra}{}^2 + \psi]} q_{rc}^{e/ra}. \tag{11}$$

The representative agent of an abstaining rich country reduces (increases) his emissions when a rise (decline) in his poorer counterparts' emissions is expected. His reaction is intensified by the poorer population's relative size. If $\phi_{ra}\delta N_{rc} P_{rc}(N_r - N_{rc}) P_{ra} > \psi$, he also reduces (increases) his emissions when a rise (decline) in the coalition's per capita emissions is expected. His reactions are moderated by his marginal international reputation and political loss, ψ, engendered by a deviation from the coalition's per capita emission. The first term on the right-hand side of equation (11) indicates the abstaining rich countries' optimal per capita emission in the absence of emissions from other sources.

4. Inaccurate expectations, guilt and equilibrium emissions

In computing the equilibrium emissions (denoted by asterisk), let us assume that some of the expectations of the three types of countries about each-other's emissions are not necessarily accurate. It is possible that, being impressed by the coalition's environmental initiatives, the abstaining countries overstate the emission-moderating effect of the emission tax and hence understate the per capita emissions of the coalition. By the same rationale it is further possible that the higher the tax rate is the stronger the abstaining countries' impression and, consequently, understatement of the coalition's actual emission. With $\varepsilon_{ra}(\tau) \geq 0$ and $\varepsilon_p(\tau) \geq 0$ indicating the expectation errors of the abstaining rich countries and the poor countries, respectively, and with gradients $\varepsilon'_{ra}(\tau) \geq 0$ and $\varepsilon'_p(\tau) \geq 0$, let us consider the case where $q_{ra}^{e/rc} = q_{ra}^*$, $q_p^{e/rc} = q_p^*$, $q_p^{e/ra} = q_p^*$ and $q_{ra}^{e/p} = q_{ra}^*$, $q_{rc}^{e/ra} = q_{rc}^* - \varepsilon_{ra}(\tau)$ and $q_{rc}^{e/p} = q_{rc}^* - \varepsilon_p(\tau)$. It can be expected that the abstaining countries' understatement of the coalition's emissions contributes to global emissions.

On the other hand, it is possible that the coalition's environmental initiatives intensify the abstaining countries' sense of guilt and moderates their free-riding. It is further possible that the higher the coalition's emission tax is the stronger the guilt sensed by the abstaining countries. Their intensified sense of guilt can be manifested in increased concerns about the environment: $\phi'_{ra}(\tau) \geq 0$ and $\phi'_p(\tau) \geq 0$ with zero-gradient indicating guilt-insensitivity.

The incorporation of the said expectations and possible concern-intensifying guilt into the reaction equations (9)-(11) leads to:

$$q_p^* = \left(\frac{\gamma_p\alpha}{2\phi_p(\tau)\delta(N_pP_p)^2}\right) - \left(\frac{N_{rc}P_{rc}}{N_pP_p}\right)[q_{rc}^* - \varepsilon_p(\tau)] - \left(\frac{(N_r - N_{rc})P_{ra}}{N_pP_p}\right)q_{ra}^* \tag{12}$$

$$q_{rc}^* = \left(\frac{\gamma_{rc}(\alpha+\eta-\tau)}{2[\phi_{rc}\delta N_{rc}P_{rc} - \beta\tau]N_{rc}P_{rc}}\right) - \left(\frac{\phi_{rc}\delta N_pP_p}{\phi_{rc}\delta N_{rc}P_{rc} - \beta\tau}\right)q_p^* - \left(\frac{\phi_{rc}\delta(N_r - N_{rc})P_{ra}}{\phi_{rc}\delta N_{rc}P_{rc} - \beta\tau}\right)q_{ra}^* \tag{13}$$

$$\begin{aligned} q_{ra}^* = {} & \frac{0.5\gamma_{ra}(\alpha+\eta)}{[\phi_{ra}(\tau)\delta(N_r - N_{rc})^2 P_{ra}{}^2 + \psi]} \\ & - \frac{\phi_{ra}(\tau)\delta N_pP_p(N_r - N_{rc})P_r}{[\phi_{ra}(\tau)\delta(N_r - N_{rc})^2 P_{ra}{}^2 + \psi]}q_p^* - \frac{[\phi_{ra}(\tau)\delta N_{rc}P_{rc}(N_r - N_{rc})P_{ra} - \psi]}{[\phi_{ra}(\tau)\delta(N_r - N_{rc})^2 P_{ra}{}^2 + \psi]}[q_{rc}^* - \varepsilon_{ra}(\tau)]. \end{aligned} \tag{14}$$

In turn, the equilibrium emissions are:[1]

$$q_{rc}^* = \left(\frac{1}{2\beta\tau}\right)\left[\frac{[\phi_{rc}/\phi_p(\tau)]\gamma_p\alpha}{N_pP_p} - \frac{\gamma_{rc}(\alpha+\eta-\tau)}{N_{rc}P_{rc}} + 2\phi_{rc}\delta N_pP_p\varepsilon_p(\tau)\right] \tag{15}$$

$$\begin{aligned} q_{ra}^* = {} & q_{rc}^* - \varepsilon_{ra}(\tau) \\ & + \frac{1}{2\psi}\left[\gamma_{ra}(\alpha+\eta) - \frac{\phi_{ra}(\tau)(N_r - N_{rc})P_{ra}\gamma_p\alpha}{\phi_p(\tau)N_pP_p} + 2\phi_{ra}(\tau)\delta N_{rc}P_{rc}(N_r - N_{rc})P_{ra}[\varepsilon_{ra}(\tau) - \varepsilon_p(\tau)]\right] \end{aligned} \tag{16}$$

$$\begin{aligned} q_p^* = {} & \left(\frac{\gamma_p\alpha}{2\phi_p(\tau)\delta(N_pP_p)^2}\right) + \left(\frac{N_{rc}P_{rc}}{N_pP_p}\right)\varepsilon_p(\tau) + \left(\frac{(N_r - N_{rc})P_{ra}}{N_pP_p}\right)\varepsilon_{ra}(\tau) \\ & - \left(\frac{(N_r - N_{rc})P_{ra}}{N_pP_p}\right)\frac{1}{2\psi}\left[\gamma_{ra}(\alpha+\eta) - \frac{\phi_{ra}(\tau)(N_r - N_{rc})P_{ra}\gamma_p\alpha}{\phi_p(\tau)N_pP_p} + 2\phi_{ra}(\tau)\delta N_{rc}P_{rc}(N_r - N_{rc})P_{ra}[\varepsilon_{ra}(\tau) - \varepsilon(\tau)_p]\right] \\ & - \left(\frac{N_{rc}P_{rc} + (N_r - N_{rc})P_{ra}}{N_pP_p}\right)q_{rc}^*. \end{aligned} \tag{17}$$

The equilibrium global emissions are:

$$Q^* \equiv N_{rc}P_{rc}q_{rc}^* + (N_r - N_{rc})P_{ra}q_{ra}^* + N_pP_pq_p^* = \frac{\gamma_p\alpha}{2\phi_p(\tau)\delta N_pP_p} + N_{rc}P_{rc}\varepsilon_p(\tau)\,. \tag{18}$$

If entree to, and exit from, the coalition are free and motivated by utility gains, the emission-tax rate that ensures the stability of N_{rc} strong coalition is a $\hat{\tau}$ maintaining equality between

[1] Equations (15) and (16) are obtained by substituting the right-hand side of (12) into (13) and (14), respectively, and rearranging and collecting terms. Equation (17) is obtained by substituting the right-hand side of equation (16) into equation (12)

the utility of the residents of the coalition and the utility of residents of the abstaining rich countries with equilibrium emissions.

5. Conclusion

The equilibrium indicated in (15)-(18) leads to the following propositions and concluding remarks.

Proposition 1: *If* $\{[\phi_{rc}/\phi_p(\tau)]\gamma_p\alpha[1+\tau\phi_p'(\tau)/\phi_p(\tau)]/(N_pP_p)+2\phi_{rc}\delta N_pP_p\varepsilon_p(\tau)\}$ *is larger (smaller) than* $[\gamma_{rc}(\alpha+\eta)/(N_{rc}P_{rc})+2\phi_{rc}\delta N_pP_p\varepsilon_p'(\tau)\tau]$, *then a unilateral implementation of emission tax and a concerted green investment of the tax revenues by a coalition of rich countries reduce (increase) the coalition's per capita emissions.* (See Appendix for a proof.)

The effectiveness of the tax in reducing the coalition's emissions increases with the poor countries' sense of guilt, but diminishes with the poor countries inclination to overstate the moderating effect of tax on the coalition's emissions.

Proposition 2: *If* $\gamma_{ra}(\alpha+\eta)+2\phi_{ra}(\tau)\delta N_{rc}P_{rc}(N_r-N_{rc})P_{ra}[\varepsilon_{ra}(\tau)-\varepsilon_p(\tau)]$ *is greater (smaller) than* $[(N_r-N_{rc})P_{ra}/(N_pP_p)][\phi_{ra}(\tau)/\phi_p(\tau)]\gamma_p\alpha+2\psi\varepsilon_{ra}(\tau)$, *then the per capita emission of the abstaining rich countries is larger (smaller) than the per capita emission in the emission tax collecting and investing coalition.* (Straightforward from equation (16))

The possibility of a positive per capita emission differential between the abstaining rich countries and the coalition increases with the abstaining rich countries' utility from the output facilitated by a unit of emission. It also increases with the coalition-emission's understatement differential between the abstaining rich countries and the poor countries, amplified by the footprint coefficient, by the abstaining rich countries' population and degree of concern for the environment and by the coalition's population. This possibility diminishes with the abstaining countries' loss of international reputation stemming from understating the coalition's per capita emission. It also diminishes with the poor-countries' utility from the output facilitated by a unit of emission, weighted by the abstaining rich countries' relative population and degree of concern about the environment.

Proposition 3: *If*

$$\left[\frac{\phi_p'(\tau)}{\varepsilon_p'(\tau)}\right] \begin{smallmatrix}>\\=\\<\end{smallmatrix} \left[\frac{2\phi_p(\tau)^2\delta N_pP_pN_{rc}P_{rc}}{\gamma_p\alpha}\right]$$

then the global emissions are reduced, not affected, or increased by the emission-tax set by the coalition. (See Appendix for a proof.)

This proposition indicates the critical ratio of the poor-countries' guilt-sensitivity to their inclination to overstate the effect of emission-tax above which the implementation of emission-tax by the coalition leads to reduction of global emissions. Equation (18) further reveals that when the poor countries do not overstate the emission tax's effect on the coalition's emissions and do not feel guilty about abstaining, the level of the global emissions is not affected by the emission-tax rate set by the coalition.

APPENDIX

Proof of Proposition 1: From (12),

$$\frac{\partial q_{rc}^{*}}{\partial \tau} = \frac{\gamma_{rc}}{2\beta\tau N_{rc}P_{rc}} - \frac{\phi_{rc}\gamma_{p}\alpha\phi_{p}'(\tau)}{2\beta\tau\phi_{p}(\tau)^{2}N_{p}P_{p}} + \frac{2\phi_{rc}\delta N_{p}P_{p}\varepsilon_{p}'(\tau)}{2\beta\tau}$$
$$+\frac{1}{2\beta\tau^{2}}\left(\frac{\gamma_{rc}(\alpha+\eta-\tau)}{N_{rc}P_{rc}} - \frac{[\phi_{rc}/\phi_{p}(\tau)]\gamma_{p}\alpha}{N_{p}P_{p}} - 2\phi_{rc}\delta N_{p}P_{p}\varepsilon_{p}(\tau)\right)$$
$$= \frac{\gamma_{rc}}{2\beta\tau N_{rc}P_{rc}}\left(1+\frac{(\alpha+\eta-\tau)}{\tau}\right) - \frac{1}{2\beta\tau^{2}}\left(\frac{[\phi_{rc}/\phi_{p}(\tau)]\gamma_{p}\alpha}{N_{p}P_{p}} + 2\phi_{rc}\delta N_{p}P_{p}\varepsilon_{p}(\tau)\right)$$
$$-\frac{\phi_{rc}\gamma_{p}\alpha\phi_{p}'(\tau)}{2\beta\tau\phi_{p}(\tau)^{2}N_{p}P_{p}} + \frac{2\phi_{rc}\delta N_{p}P_{p}\varepsilon_{p}'(\tau)}{2\beta\tau}$$
$$= \frac{1}{2\beta\tau^{2}}\left[\frac{\gamma_{rc}(\alpha+\eta)}{N_{rc}P_{rc}} - \frac{[\phi_{rc}/\phi_{p}(\tau)]\gamma_{p}\alpha[1+\tau\phi_{p}'(\tau)/\phi_{p}(\tau)]}{N_{p}P_{p}} - 2\phi_{rc}\delta N_{p}P_{p}[\varepsilon_{p}(\tau)-\varepsilon_{p}'(\tau)\tau]\right].$$

Proof of Proposition 3: The equilibrium global emissions are:

$$Q^{*} \equiv N_{rc}P_{rc}q_{rc}^{*} + (N_{r}-N_{rc})P_{ra}q_{ra}^{*} + N_{p}P_{p}q_{p}^{*}\,.$$

Recalling (15), (16) and (17),

$$Q^{*} = \frac{\gamma_{p}\alpha}{2\phi_{p}(\tau)\delta N_{p}P_{p}} + N_{rc}P_{rc}\varepsilon_{p}(\tau)$$

Hence,

$$\frac{\partial Q^{*}}{\partial \tau} \underset{>}{\overset{<}{=}} 0 \text{ as } \left[\frac{\phi_{p}'(\tau)}{\varepsilon_{p}'(\tau)}\right] \underset{<}{\overset{>}{=}} \left[\frac{2\phi_{p}(\tau)^{2}\delta N_{p}P_{p}N_{rc}P_{rc}}{\gamma_{p}\alpha}\right].$$

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