Multimarket interdependent energy strategies
with an emission permits regulation

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Abstract
This paper investigates the interactions between energies (fossil fuel and renewable) market and an international market for emission permits. The price of permits affects the energy market equilibrium, which also alters the emission levels. With implementation of the Kyoto Protocol, Russia (the FSU) will be able to exert market power in the emission of permit. Hence, Russia faces a trade-off between maximising its permits revenue and preserving its rents from energy exports. Russia is most likely to adopt a strategic behaviour. Involving in the Kyoto protocol, the European Union (the EU) aims also to reach an efficient distribution of its energy consumption based both on its energy exports and the development of its renewable energy. This paper analyses the interdependence of the energy and the emission permits markets using a general equilibrium approach. We show that the coordination of FSU strategies on the brown and the permits market affects strategic behaviour on the energies market, which in turn impact the permits price and the environmental cost-effectiveness. The impact depends crucially on the degree of substitutability between the brown and the green energies. A monopoly behaviour exerted by the FSU on the permits market leads to a sharp fall of the brown energy price if the green energy is a highly substitute with the brown, which induces also reduction of the FSU market shares on the energy market.

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1 Introduction

The Kyoto protocol marks an achievement in the international negotiations on climate change. This agreement commits the participating countries (referred to as Annex-1 countries) to limit their green house gases (GHG) emissions. On average, these countries aim to reduce their emissions to roughly 5.2% from 1990 emission levels by 2008-2012. To fulfil this objective, a tradable permits market has been implemented through a trading of emission reduction, so-called assigned amounts units (AAUs). Since the US withdrawal from the Kyoto protocol, the Former Soviet Union (the FSU) has become a dominant player in the international climate policy. The FSU may have an incentive to exert a market power position as a consequence of the “hot air” situation. The FSU strategy on the permits market is also related to the energy market outcome, as the FSU is a major exporter of brown energy (e.g. fuel, gas, ...). This brown energy is a highly polluting energy source harming the environment compared to the green energy, which is thought to be an environmentally friendly source of energy referring to renewable and lower polluting energy sources (e.g. wind, water, biomass, solar, ....). In this context, due to the GHG constraints, the international energy prices would rather fall (Montgomery and Bernstein (2000)).

The interdependence of the energy and the permits markets leads to a bilateral externality. The permits price impacts the energy market equilibrium, which also alters the emission levels. Hence, the FSU faces a trade-off between exerting market power in the permits market and preserving its export revenues.

\footnote{As a consequence of the economic downturn with the collapse of the Soviet Union, emission declined sharply in the early 1990s, remaining 32\% lower than their 1990 level. The FSU is then able to meets its commitment targets with minimal efforts and could flood the international permits market, reducing incentives for the other Annex-1 countries to cut their domestic emissions. This situation is referred to as “hot air” (Victor et al. (1998)). Kotov (2002) reports also that the Russian emissions from the energy sector are forecasted at 85\% of their 1990 level.}
on the energy markets. This raises the issue for the FSU to adopt a strategic behaviour taking account of this interplay. A possible solution for the FSU to deal with these externalities caused by interdependent markets would be to redistribute permits to the brown energy producers. This way, the brown energy producer would maximize joint profits and take account of the interaction between the two markets. In particular, Moe and Tangen (2000) suggest that Russia is likely to leave the control of permits to large exporting gas producers such as Gazprom. Thus, this seems to be a relevant alternative for the FSU to exert a multimarket coordinated strategy. The European Union (EU) is also a key player in the international climate policy. The EU is both engaged in the international permits trading and aims to reach an efficient distribution of its energy consumption based both on the FSU and the ROW (Rest of the World) energy exports and the development of its renewable energy (Spanjer (2007)). In this context, the Directive on Electricity Production from Renewable Energy Sources 2001/77/EC\(^2\) promotes the use of renewable energy sources in EU electricity production.

This paper intends to shed some light on the interdependence of the energy and the emission permits markets. It describes the main implications, of the FSU multimarket coordination, on the energetical consumption choices of importing countries and the environmental cost-effectiveness. This *environmental cost-effectiveness* refers to the minimum cost of meeting the GHG constraint according to the FSU strategic behaviour.

The option to exert a market power strategy in the FSU takes theoretically the

\(^2\)The directive 2001/77/EC sets national "indicative" targets for renewable energy production from individual member states. The European Commission will monitor the progress made by the Member States in pursuing national targets and will if necessary propose mandatory targets for States failing to achieve their targets. This directive leads to the development of a green certificate market.
form of a simple cost-price manipulation - so called Cost minimizing manipulation (Hahn (1984), Westog and Barron (1999)) – to extract the rent form the international permits trading. Empirical studies confirm these considerations (Holtsmark (2003), Böhringer and Löschel (2003)). On the one hand, by imposing a too high permits price the FSU may reduce fossil energy use in the other Annex-1 countries and decrease the international fossil fuel price (Bernard et al. (2003)). On the other hand, it may induce a substitution from fossil fuel to lower polluting intensive energies. This interdependence between the energy and the permits markets has received little attention. Holstmark and Maestrad (2002) study the profitability for a fossil fuel country to coordinate its dominant strategies on the fossil fuel energy and the permits market. Hagem et al. (2006a, 2006b) emphasize that by coordinating its strategies, the FSU might reduce its optimal mark-up on the permits market. First, they show that this reduction depends on the degree of substitution between the energies available on the market. Second, they provide numerical results to illustrate that the FSU has an incentive to coordinate its permits exports with its oil and gas exports in the context of the Kyoto protocol.

Our paper goes further by investigating the theoretical impact of the FSU potential market strategies coordination, on the energetical choice of the importing countries and the environmental cost-effectiveness. The first-best allocation is also provided to analyze the optimal equilibrium on the energies and the permits markets. Our model has two key features. First, we allow for an oligopolistic competition in the international market for the brown energy between the Former Soviet Union and the Rest of the World taking into account the existence for the European Union to develop its renewable energy (referred to as green
energy). Second, we analyze the interactions between the international energy market and the international emission trading considering the possibility of coordinated market power exerted by the Former Soviet Union. Within this context, we model the interaction between the imperfect competitive market structure and a multilateral environmental externality on polluting emissions. We show that the coordination of FSU strategies on the brown and the permits market affects strategic behaviour on the brown energy market vis-à-vis the ROW, the permits price and the environment cost-effectiveness. The impact depends crucially on the degree of substitutability between the brown and the green energies. In particular, when the green and the brown energy are strong substitutes, an increase of the FSU emissions enhances the permits price, which in turn induces a shift in the EU energy consumption in favor of the green energy. Furthermore, in that case, coordination is desirable in term of environmental effectiveness as it decreases the total cost of meeting the GHG constraint with respect to the non coordinated monopoly scenario.

This paper is organized as follows. Section 2 presents the model. Section 3 characterizes the benchmark case within a perfectly competitive permits market. Section 4 considers the possibility for the FSU to distort its abatement strategy to act as a dominant seller in the international permits market. Section 5 extends the model to take into account the interplay between the brown energy and the permits markets. It considers the impact of the FSU internalization of the bilateral externality between the brown energy and permits sellings through the distribution of permits to the brown energy producer. We refer to this as the coordination case. Section 6 concludes.

All the proofs of propositions for this chapter are available in appendix.
2 The model

We start by formally describing the key features and assumptions of our model taking the form of a simultaneous game. With this model we intend to analyze the strategic interactions between countries on the permits and the energy, brown and green markets. The use of these energies participates to the total amount of pollution and some countries commit themselves to reduce emissions within the framework of the Kyoto protocol through an international permits market. The economy we consider in our model is composed of three groups of countries interacting on four markets.

2.1 The group of countries

The Former Soviet Union (FSU)

The FSU is a brown energy producer participating at the Kyoto protocol. It exports its production of brown energy denoted by $x_{fsu}^b$ to the EU.\(^3\) The extraction cost of brown energy is $C_b$ ($C_b' > 0$ and $C_b'' \geq 0$). The FSU pollutes at a level $e_{fsu}^f$ and has to meet its assigned amount units of emissions $e_{fsu}^f$ set by the Kyoto protocol. For satisfying its environmental constraint, the FSU can depollute with an heterogeneous abatement cost $-A_{fsu}^f$ (with $-A_{fsu}^f > 0$ and $-A_{fsu}^f'' \leq 0$) and/or fit its permits endowment to its emissions level.

The FSU gas producer sets its exports of brown energy $x_{fsu}^b$ so as to maximize its profit given by

$$\pi_{fsu}^b = p_b(x_{fsu}^b)x_{fsu}^b - C_b(x_{fsu}^b)$$

The FSU permits exporter chooses the level of emissions $e_{fsu}^f$ so as to maximize

\(^3\)The FSU consumes also brown energy but this market cannot be treated as integrated to the EU market as it is heavily regulated. We therefore ignore FSU domestic consumption in our model.
its profit from permits exports given by:

\[ \pi_{p}^{f} = q \left( \bar{\pi}_{p}^{f} - e^{f} \right) - A^{f}(e^{f}) \]

The Rest of the World (ROW):

The ROW\(^4\) exports all its production of brown energy \(x_{b}^{\text{row}}\) to the European Union. We assume that the extraction cost of brown energy \(C_{b}\) of the ROW is the same as the FSU extraction cost.

The ROW sets its exports of brown energy \(x_{b}^{\text{row}}\) so as to maximize its profit

\[ \pi_{b}^{\text{row}} = p_{b}(x_{b})x_{b}^{\text{row}} - C_{b}(x_{b}^{\text{row}}) \]

The European Union (EU):

The EU produces an homogenous good \(y\) with two types of energy inputs (a brown energy and a green energy). The EU production technology for the good \(y\) is \(y = f(x_{b}, x_{g})\). The brown energy is imported from the FSU and the ROW that is \(x_{b} = x_{b}^{fsu} + x_{b}^{\text{row}}\). The green energy is produced at a cost \(C_{g}\) with \(C'_{g} > 0\) and \(C''_{g} \geq 0\). The EU pollutes at a level \(e^{eu} = \gamma_{g}x_{g} + \gamma_{b}x_{b}\) and has to meet its assigned amount units of emissions \(e^{eu}\) set by the Kyoto protocol. For satisfying its environmental constraint, the EU can depollute with an heterogeneous abatement cost \(-A^{eu}\) (with \(-A'^{eu} > 0\) and \(-A''^{eu} \leq 0\)) and/or fit its permits endowment to its emissions level.

The EU sets its imports of brown energy \(x_{b}\) and its level of green energy \(x_{g}\) by maximizing its profit \(\pi^{eu}\). This determines implicitly its level of emissions.

\(^4\)The ROW is not committed to a reduction on its emissions as the Kyoto protocol implements only an international permits market among the Annex-1 countries.
2.2 The markets

The decisions of the countries on the different markets are taken simultaneously. This reflects the strategic interdependence of the energy and the permits markets.

The brown energy market:
The FSU and the ROW compete in a Cournot fashion on the brown energy market for the European exports. The price of the brown energy \( p_b \) depends on the levels of extraction resulting from the game between the ROW and the FSU. The equilibrium condition in the brown energy market is:

\[
x_{b}^{\text{row}}(p_b) + x_{b}^{\text{fsu}}(p_b) = x_b(p_b)
\]  

(1)

The green energy market:
The green energy market is competitive and only takes place within the European Union. The European countries are the only suppliers and consumers of the green energy at the world level. The green input is then priced at its cost of production.

The good y market:
The good y market is perfectly competitive. The EU sells its production of good y on the international product market at the equilibrium price \( p_y \).

The emission permits market:
At the international level, the FSU and the EU are committed to reduce their emissions. A market mechanism through an international tradeable emission permits system imposes a quota on the domestic level of emissions. These emission permits are traded at the permits price \( q \) without any transaction costs.
The results of the game between the FSU, the ROW and the EU on the energy markets and the price $q$ depend on the FSU behavior on the international permits market. Indeed, the FSU has the potential for market power on the emission permits market. It may decide to behave competitively or to adopt a monopoly permits pricing strategy. Due to the interdependence of the energy and the permits markets, the FSU might choose to coordinate its strategic position on the permits market with its position on the brown energy market. We therefore consider three alternative market structures on the permits trading: the competitive case, the monopoly case and the coordinated market power case. In the competitive and the monopoly case, the FSU brown energy producer and the permit exporter are separate entities whereas in the coordinated monopoly case, permits are supposed to be allocated to the gas producer that maximizes joint profits. The equilibrium condition in the emission permits market is:

$$e^{eu}(q) + e^{fsu}(q) = e^{eu} + e^{fsu}$$

(2)

The main elements of the model are summarized in figure 1.
3 The competitive permits market case

Consider as a reference case a situation in which the permits market is perfectly competitive. The brown energy production levels are the result of a Cournot game between the FSU and the ROW. We first determine the reaction function of the FSU to the ROW decision on the brown market and the FSU level of
domestic emissions. Second, we compute the reaction function of the ROW to the FSU on the brown energy market to solve the Cournot game. Third, we turn to the energetical choices of the EU. Last, we explain the subsequent mechanism determining the permits price formation in the case of a competitive emission permits market.

3.1 The Former Soviet Union

The FSU producer of brown energy competes in a Cournot fashion with the ROW producer. It fixes its level of brown energy exports so as to maximize its profit:

$$\max_{x_b^{fsu}} \pi_b^{fsu} = p_b(x_b) x_b^{fsu} - C_b(x_b^{fsu})$$

The first order condition is:

$$\frac{\partial \pi_b^{fsu}}{\partial x_b^{fsu}} = \frac{\partial p_b(x_b)}{\partial x_b} x_b^{fsu} + \left( p_b(x_b) - \frac{\partial C_b(x_b^{fsu})}{\partial x_b^{fsu}} \right) = 0$$

(3)

The first left hand term of equation (3) represents the effect of an extra unit of brown energy on the profitability of inframarginal ones. The other terms express the profitability of an extra unit of brown energy. There is a negative externality between the ROW and the FSU. When choosing its level of brown energy exports, the FSU only takes into account the adverse effect of the market price on its own exports, rather than the effect on the aggregate exports.

Rewriting the best response of the FSU on the brown energy market to the ROW strategy given by equation (3), we obtain the classical Lerner index:

$$\frac{p_b(x_b) - \frac{\partial C_b(x_b^{fsu})}{\partial x_b^{fsu}}}{p_b(x_b)} = \frac{1}{\varepsilon_b} \frac{x_b^{fsu}}{x_b}$$

(4)
with $\varepsilon_b = -\frac{\partial p_b(x_b)}{\partial x_b}x_b$ representing the demand elasticity of the brown energy. Note that as $\frac{\partial p_b(x_b)}{\partial x_b} \leq 0$, we have that $\varepsilon_b > 0$.

The Lerner index represents the margin of one unit of brown energy. It clearly decreases with the market share of the FSU and is inversely proportional to the demand elasticity of the brown energy. The permits exporter fixes its level of domestic emissions $e^{fsu}$ so as to maximize its profit:

$$\max_{e^{fsu}} \pi^{fsu}_p = -q(e^{fsu} - \pi^{fsu}) - A^{fsu}(e^{fsu})$$

After computation, the first order conditions\(^5\) give:

$$\frac{\partial \pi^{fsu}_p}{\partial e^{fsu}} = -q - \frac{\partial A^{fsu}(e^{fsu})}{\partial e^{fsu}} = 0 \quad (5)$$

which can be rewritten as:

$$q^* = -\frac{\partial A^{fsu}(e^{fsu})}{\partial e^{fsu}} \quad (6)$$

Equation (6) determines the optimal level of FSU emissions ($e^{fsu}$). The FSU is price taker in the permits market. It sets its emissions level to equalize its marginal abatement cost to the permits price. In effect, the FSU either reduces its sellings of permits and loses the associated opportunity cost $q$ or abates this emission incurring a cost of $-\frac{\partial A^{fsu}(e^{fsu})}{\partial e^{fsu}} > 0$. This represents the indirect shadow cost associated with an additional emission in the FSU resulting from the use of an additional brown energy unit.

### 3.2 The Rest of the World

The ROW interacts in a Cournot fashion with the FSU on the brown energy market. It sets its exports of brown energy to the EU so as to maximize its

\(^5\)The second order condition given by $\frac{\partial^2 p_b(x_b)}{\partial x_b^2}x_b^{fsu} + 2\frac{\partial p_b(x_b)}{\partial x_b} + \frac{\partial^2 C_b(x_b^{fsu})}{\partial x_b^2}$ is satisfied as, $C_b''(x_b^{fsu}) \leq 0$ and $p_b''(x_b)x_b^{fsu} + 2p_b'(x_b) \leq 0$ (see Dixit (1986)).
profit given by:
\[ \max_{x_b^{row}} \pi_b^{row} = p_b(x_b) x_b^{row} - C_b(x_b^{row}) \] (7)

The first order condition is:
\[ \frac{\partial \pi_b^{row}}{\partial x_b^{row}} = \frac{\partial p_b(x_b)}{\partial x_b} x_b^{row} + p_b(x_b) - \frac{\partial C_b(x_b^{row})}{\partial x_b^{row}} = 0 \] (8)

Rewriting the best response of the ROW on the brown energy market to the FSU strategy given by equation (8), we have:
\[ \frac{p_b(x_b) - \frac{\partial C_b(x_b^{row})}{\partial x_b^{row}}}{p_b(x_b)} = \frac{1}{\varepsilon_b} \frac{x_b^{row}}{x_b} \] (9)

As \( \varepsilon_b \geq 0 \), the ROW and the FSU export the brown energy at a price exceeding marginal cost. We obtain the classical result of a Cournot equilibrium. This equilibrium is not socially efficient as the brown energy is not priced at marginal cost. This results from the market power of the FSU and the ROW on the brown energy market.

3.3 The European Union

Let us turn to the strategy of the EU on the energy and the permits markets. The EU fixes its level of imports of brown energy \( x_b \) and determines its level of green energy consumption \( x_g \). Then, the EU domestic level of emissions \( e^{eu} \) derives directly from these former levels of energy input consumptions. This implies that the EU considers the following maximization program, under technical constraints:
\[ \max_{x_b, x_g} \pi^{eu} = p_y y - p_b(x_b) x_b - C_g(x_g) - q(e^{eu} - \bar{e}^{eu}) - A^{eu}(e^{eu}) \] (10)
\[ y = f(x_b, x_g) \] (11)
\[ e^{eu} = \gamma_g x_g + \gamma_b x_b \] (12)
where condition (11) represents the EU production technical constraint and condition (12) the emissions structure.

After computation, the first order conditions give:

\[
\frac{\partial \pi^u}{\partial x_b} = p_y \frac{\partial f(x_b, x_g)}{\partial x_b} - p_b(x_b) - \gamma_b \left( q + \frac{\partial A^u(e^u)}{\partial e^u} \right) = 0 \quad (13)
\]

\[
\frac{\partial \pi^u}{\partial x_g} = p_y \frac{\partial f(x_b, x_g)}{\partial x_g} - \frac{\partial C_g(x_g)}{\partial x_g} - \gamma_g \left( q + \frac{\partial A^u(e^u)}{\partial e^u} \right) = 0 \quad (14)
\]

**Definition 1** The Energetical Marginal Rate of Substitution of brown energy for green energy is defined as \( EMRS_{x_b/x_g} = \frac{\partial f(x_b, x_g)}{\partial x_b} = \frac{\partial f(x_b, x_g)}{\partial x_g} \). It measures the additional amount of green input that must be used to keep output level constant when the amount of brown input is decreased marginally.

Note that the EMRS is the ratio between the marginal productivity of the brown and the green energy factors. It represents the EU subjective rate of substitution between the brown and the green energy inputs for a given production level \( y \).

Rearranging conditions (13) and (14) gives the form of the implicit optimal levels of brown and green energy consumption \( x_b(e^u, x_g) \) and \( x_g(e^u, x_b) \). These are such that:

\[
EMRS_{x_b/x_g} = \frac{\frac{\partial f(x_b, x_g)}{\partial x_b}}{\frac{\partial f(x_b, x_g)}{\partial x_g}} = p_b(x_b) + \left[ \gamma_b \left( q + \frac{\partial A^u(e^u)}{\partial e^u} \right) \right] \frac{\partial f(x_b, x_g)}{\partial x_b} + \left[ \gamma_g \left( q + \frac{\partial A^u(e^u)}{\partial e^u} \right) \right] \frac{\partial f(x_b, x_g)}{\partial x_g} \quad (15)
\]

The right hand side of equation (15) represents the objective exchange rate. It is the ratio between the explicit prices of the energy factors. The *explicit price of a factor* is defined as the sum of the factor market price and the indirect shadow cost of an additional emission, resulting from an additional use of factor. This ratio depends on the respective pollution intensity of energetical production factors and on the permits price. The EU chooses its levels of
energy consumption by equalizing its subjective rate to the objective exchange rate of factors. Thus, ceteris paribus, an increase in the permits price impacts explicit prices and modifies the production combination of energetical factors of the EU. The behaviour of the FSU on the permits market affects EU energy consumption of brown energy. It may affect the brown energy price and the associated FSU and ROW exports revenues.

3.4 The permits market equilibrium

This subsection describes the subsequent mechanism determining the emission permits price. Conditions (6) and (13)-(14) give:

\[ q = - \frac{\partial A^{fsu}(e^{fsu})}{\partial e^{fsu}} \]

\[ = \frac{1}{\gamma_b} \left( p_y \frac{\partial f(x_b, x_g)}{\partial x_b} - p_b(x_b) \right) - \frac{\partial A^{eu}(e^{eu})}{\partial e^{eu}} \]

\[ = \frac{1}{\gamma_g} \left( p_y \frac{\partial f(x_b, x_g)}{\partial x_g} - \frac{\partial C_g(x_g)}{\partial x_g} \right) - \frac{\partial A^{eu}(e^{eu})}{\partial e^{eu}} \]

The first term of the right hand side of equation (17) and equation (18) represent the net marginal benefit resulting from the use of one unit of emission. Define the net marginal abatement cost as the sum of the net marginal benefit and the marginal abatement cost for one unit of emission, resulting from the consumption of an additional unit of energy factor. Conditions (16)-(18) imply the equalization of net marginal abatement costs from own emissions reduction across countries to the international permits price. This proposition is in accordance with the results presented in Montgomery (1972). As a consequence when the FSU is price taker in the permits market, it sets its level of emission such that its net marginal abatement cost is equal to the permits price. The valuation for an additional unit of pollution is then identical between the FSU
and the EU, resulting in an equalization of their willingness to pay for one unit of emission.

For the FSU, rearranging condition (5) yields to define $e^{fsu} = e^{fsu}(q)$ as an implicit function of the permits price $q$. In a similar way for the EU, conditions (17) and (18) leads to determine $e^{eu} = e^{eu}(q)$ as an implicit function of the permits price $q$. The equilibrium permits price $q^*$ is thus implicitly given by the market clearing condition (2). This competitive permits market equilibrium yields to implement an effective equilibrium, known as the cost-minimizing solution. This refers to a solution where the aggregate abatement cost to fit the environmental constraint over all countries is minimized.

4 The monopoly case

The behavior of the EU, the ROW and the FSU gas producer are the same as in section 2. However in the monopoly case, the FSU permits exporter (as a dominant seller) takes into account its influence on the international permits price resulting from the hot air situation.

4.1 The Former Soviet Union

The FSU permits exporter can now flood the permits market and distort its choice on emissions to exert its market power. The permits price is then endogenous to the FSU permits sellings $e^{fsu}$ i.e. $q(e^{fsu})$. The FSU maximization program with market power becomes:

$$\max_{e^{fsu}} \pi_{p}^{fsu} = q(e^{fsu})(\pi^{fsu} - e^{fsu}) - A^{fsu}(e^{fsu})$$

The FSU emissions level is now given by:
\[
\frac{\partial \pi^{fsu}_p}{\partial \ell^{fsu}} = -q - \frac{\partial A^{fsu}_l(e^{fsu})}{\partial e^{fsu}} - \frac{\partial q}{\partial e^{fsu}} (e^{fsu} - \tau^{fsu}) = 0
\]

that can be rewritten as

\[
q + \frac{\partial q}{\partial e^{fsu}} (e^{fsu} - \tau^{fsu}) = -\frac{\partial A^{fsu}_l(e^{fsu})}{\partial e^{fsu}}
\]

(19)

The left hand side of equation (19) represents the FSU marginal revenue from the selling of one more permit. We find the classical monopoly pricing rule. Figure 2 illustrates the distortion on the permits market resulted from the exercise of the FSU monopoly power.

Figure 2: Emissions Monopoly - competition

| MR | Marginal revenue from one permit |
| MAC | Marginal Abatement Cost |

The FSU decreases the level of permits exports in order to raise the permits price and benefit of a higher per unit revenue. The FSU considers the
positive impact on marginal revenue of increasing its emissions from one unit. By emitting more, the FSU lowers its abatement level and reduces its permits supply. In turn, the international permits price increases to its monopoly level \( q^M \), exceeding its competitive level \( q^* \).

4.2 The European Union

The first order conditions for the European Union do not change. The change in the strategic behaviour of the FSU in the permits market only implies a move along the demand curves of brown and green energy. Thus, a change in the pricing strategy of the FSU just impacts the EU level of the demand for both types of energy leaving unchanged the reaction functions form. Using relation (12) and the First order conditions (13)-(14), we obtain the incidence of permits price increase on the green and the brown energy consumptions:

\[
\frac{\partial x_b}{\partial q} = \left[ \frac{\partial x_b}{\partial e^{cu}} \frac{\partial e^{cu}}{\partial q} \right] + \left[ \frac{\partial x_b}{\partial x_g} \frac{\partial x_g}{\partial e^{cu}} \frac{\partial e^{cu}}{\partial q} \right] = \left( \frac{1}{\gamma_b} - \frac{1}{\gamma_g} \times \frac{1}{EMRS_{x_b/x_g}} \right) \frac{\partial e^{cu}}{\partial q}
\]

\[
\frac{\partial x_g}{\partial q} = \left[ \frac{\partial x_g}{\partial e^{cu}} \frac{\partial e^{cu}}{\partial q} \right] + \left[ \frac{\partial x_g}{\partial x_b} \frac{\partial x_b}{\partial e^{cu}} \frac{\partial e^{cu}}{\partial q} \right] = \left( \frac{1}{\gamma_g} - \frac{1}{\gamma_b} \times \frac{1}{EMRS_{x_b/x_g}} \right) \frac{\partial e^{cu}}{\partial q}
\]

An increase in the international permits price has two effects on the brown and the green energy consumptions. It has a direct effect on the emissions associated to the green and the brown energy factors implying a drop in their consumption. It has an indirect effect via the substitution operated between the two energies. The sign of this effect depends on the respective pollution intensities of the energy factors and on their degree of substitutability. The results are summarized in proposition 1:

Proposition 1
If the green and the brown energy factors are strong substitutes (i.e. $EMRS_{x_b/x_g} > \frac{\gamma_b}{\gamma_g} > 1$) then an increase of FSU emissions drives up the permits price and reduces the EU brown energy consumption in favor of green energy consumption.

When the FSU behaves as a monopoly, it increases its level of emissions implying an increase of the permits price. The reaction of the EU to this permits price increase will depend on the degree of substitutability of the brown and the green energy. If the green and the brown energy are strong substitutes, then the indirect effect is higher than the direct effect. This means that a permits price increase leads to a higher use of green energy at the expense of the brown energy.

We now consider the main implications of a FSU monopoly behaviour exerted on the permits market for the environmental cost-effectiveness and the brown energy market.

- The environmental cost-effectiveness:

The FSU condition (19) implies that its net marginal abatement cost given by $-\frac{\partial A^{fsu}_e}{\partial e^{fsu}}$ is lower than its competitive level. The monopoly permits price $q^M$ is higher than the competitive price $q^*$. On the one hand, the FSU is price maker on the permits market and faces a lower net marginal abatement cost than $q^M$. On the other hand, the EU is price taker on the permits market and equalizes its net marginal abatement cost to $q^M$. Then, the net marginal abatement costs are no longer similar across countries. There is a deviation from the cost-minimizing solution as a result of an increase in the total compliance costs in the EU. The monopoly equilibrium on the permits market takes the form of a cost-minimizing manipulation solution, resulting in a dead-weight
loss from an environmental cost-effectiveness consideration. This so called cost-minimizing manipulation, studied by Hahn (1984), identifies the ability of a dominant participant (a firm or a country) to influence the permits price. As the FSU manipulates the permits price, there are additional overall economic costs to achieve the same level of abatement as under the competitive equilibrium. Equation (19) shows that if the FSU does not receive an initial allocation of assigned units of emission permits $e_{fsu}^{\ell}$ equal to its emission level $(e_{fsu})^M$, then the total expenditure on abatement will exceed the cost minimizing solution. Then, once market power is considered, it is possible to neutralize the FSU dominant behaviour by assigning it an initial allocation equal to its emission level.

- The energy market:

The FSU dominant strategy on the permits market affects the energy market equilibrium. The permits price increases in the monopoly case, arising the cost of the brown energy relative to the green energy in the EU. Then the higher the degree of substitutability between the two energy factors, the higher the decrease of the brown in favour of the green energy. This results in a lower demand for the brown energy in the international market. Therefore, the FSU and the ROW reduce their supply of brown energy while the market shares on the brown energy market of the FSU and the ROW remain the same, as their reaction functions are unchanged. Then, the brown energy price is lower. This result is in accordance with the empirical evaluations.

The development of the permits market introduces a pecuniary externality, which operates through the permits price and has an indirect resource effect on decisions making in each country. Therefore, the FSU might choose to lower
this negative impact on the brown energy exports due to its monopoly behaviour on the permits market. This prompts it to coordinate its dominant strategies both on the brown energy and the permits markets.

5 The coordinated market power case

When acting as separate agents, the brown energy producer and the permit exporter do not take into account the impact they have on each other profit. As the FSU is both exerting a market power in the international permits and the brown energy markets, it could choose to coordinate its strategic positions and integrate the interplay between these two markets. It could do so by letting for instance the brown energy producer in control of emission permits. In this context, the gas producer would maximize the joint profit from gas and permits exports internalizing this way the bilateral pecuniary externality associated to the interdependence of these markets. The FSU problem is to determine, in the coordinated market power case, how to associate both rent seeking strategies on the permits and the brown energy markets. This new hypothesis on the interplay means that now the EU demand for brown energy depends on the FSU level of emissions (and thus on the permits price) and vice versa. The FSU has to integrate this new condition in its maximizing program. The brown energy producer maximizes the joint profit given by:

\[
\begin{align*}
\text{Max}_{x_{b}^{fsu}, e_{fsu}} & \pi_{fsu} = \pi_{b}^{fsu} + \pi_{p}^{fsu} \\
& = p_b(x_b, e_{fsu})x_b^{fsu} - C_b(x_b^{fsu}) - q(e_{fsu}, x_b)(e_{fsu} - \pi_{fsu}) - A^{fsu}(e_{fsu})
\end{align*}
\]

\[\text{(22)}\]

\[\text{(23)}\]

\[\text{Gazprom, the dominating Russian gas producer may be left in control of a large part of emissions permits (Moe and Tangen (2000)).}\]
The FSU program now includes the impact of a permits price modification on EU brown energy imports and the impact of a modification of the level of brown energy on the permits price. The first order conditions integrating the interdependence of the brown energy and the permits market are:

$$\frac{\partial \pi_{fsu}^{fsu}}{\partial x_b^{fsu}} = \frac{\partial p_b}{\partial x_b^{fsu}} + p_b - \frac{\partial C_b(x_b^{fsu})}{\partial x_b^{fsu}} - \frac{\partial q}{\partial x_b^{fsu}} (e^{fsu} - \bar{e}^{fsu}) = 0 \quad (24)$$

$$\frac{\partial \pi_{fsu}^{fsu}}{\partial c^{fsu}} = \frac{\partial p_b}{\partial c^{fsu}} - \frac{\partial q}{\partial c^{fsu}} (e^{fsu} - \bar{e}^{fsu}) - q - \frac{\partial A^{fsu}(e^{fsu})}{\partial c^{fsu}} \quad (25)$$

Equation (25) can be rewritten as

$$q^{MC} = \frac{\partial p_b}{\partial c^{fsu}} - \frac{\partial q}{\partial c^{fsu}} (e^{fsu} - \bar{e}^{fsu}) - \frac{\partial A^{fsu}(e^{fsu})}{\partial c^{fsu}} \quad (26)$$

From condition (25), we obtain that the permits price differs from its form in the monopoly case. The discrepancy comes from the term $\frac{\partial p_b}{\partial c^{fsu}} = \frac{\partial p_b}{\partial x_b^{fsu}} \frac{\partial x_b^{fsu}}{\partial q} \frac{\partial q}{\partial c^{fsu}}$.

The impact of FSU emissions on the brown energy price transits through the permits price. This reflects the internalization by the FSU of the interdependence between the EU brown imports and its emissions as depicted by proposition 1.

The results, illustrated by figure 3, are summarized in proposition 2:

**Proposition 2**

(i) When the brown and the green inputs are strong substitutes (i.e. $EMRS > 1$), the FSU level of emissions is lower when the FSU coordinates its positions on the brown energy and the permits markets than when it does not (i.e. $(e^{fsu})^{MC} < (e^{fsu})^M$). In that case, the coordinated monopoly permits price $q^{MC}$ is smaller than the monopoly permits price $q^M$.

(ii) When the brown and the green inputs are weak substitutes (i.e. $0 < EMRS < 1$), the FSU level of emissions is higher when the FSU coordinates its positions on the brown energy and the permits markets than when it does not (i.e.
In that case, the coordinated monopoly permits price \( q_{MC} \) is higher than the monopoly permits price \( q^M \).

When the FSU coordinates its positions on the brown energy and the permits markets, it integrates the negative impact of an increase of the permits price on its brown energy exports. Thus, when the green and the brown factors are strong substitutes, the FSU emits less to mitigate the negative impact of permits price increase on brown energy exports.

We now consider the main implications of the FSU coordinated behaviour exerted both on the brown energy and on the permits market:

- The environmental cost-effectiveness:

  The first order conditions of the EU remain the same as in the competitive and the monopoly case. Though, a change in the FSU behaviour on the permits market modifies its energy policy mix. If the brown and the green are strong substitutes, the EU will demand more brown energy when the FSU coordinates its strategic positions. In effect, if the permits price increases too much, the EU prefers to invest in green technologies as it is relatively less costly for it than consuming the brown energy. Thus, on the one hand, when the FSU coordinates its strategic positions and the green and the brown are strong substitutes, the FSU decreases its emissions in order to limit the impact of a higher permits price on brown energy exports. As a consequence, the net abatement cost is higher than in the monopoly case increasing environmental efficiency. The impact of the permits price on brown energy exports mitigate the FSU market power on the permits market limiting the cost-manipulation. On the other hand, when the brown energy is a weak substitute to the green energy, the coordination enhances the distortion on the permits market as \( q_{MC} \) is higher than \( q^M \). This prompts
the E.U to face a higher net marginal abatement cost, decreasing environmental efficiency. The results are summarized in proposition 3:

Proposition 3

*In term of environment cost-effectiveness, when the brown and the green energy are strong substitutes, the FSU coordination of strategic positions on the brown energy and the permits price markets is preferable to the non coordination as it results in a lower total cost of meeting the global environmental constraint imposed by the Kyoto protocol.*

- The energy market:

The coordinated strategy affects the FSU behaviour on the brown energy market through the permits price manipulation. However, The reaction function of the ROW remains the same. Rewriting condition (24) yields to the following modified lerner index:

$$p_b(x_b) - \frac{\partial C_b(x_b^fsu)}{\partial x_b^fsu} = \frac{1}{\varepsilon_b x_b} \frac{x_b^fsu}{x_b} + \frac{\partial q}{\partial x_b} (e^fsu - \pi^fsu)$$  \hspace{1cm} (27)

We know from the hot air situation that the FSU level of emissions is lower than its AAUs, i.e. $e^fsu - \pi^fsu < 0$.

From proposition 1, if the green and the brown energies are strong substitutes, an increase of the FSU brown energy exports leads to a fall in the permits price. The impact of the FSU coordination on the ROW strategy is depicted in proposition 4.

Proposition 4

*If the brown and the green inputs are strong substitutes (i.e. $EMRS > 1$) then the FSU market share on the brown energy market decreases to the benefit of the ROW if the FSU coordinates its strategies.*
When coordinating its positions, the FSU takes into account the negative impact of permits price increase on brown energy demand when products are strong substitutes. In order to counterbalance this negative effect on its marginal revenues from brown exports, the FSU diminishes its exports so as to counterbalance the price decrease associated to the fall of the EU demand due to the permits price modification. Thus, there is a change is the FSU reaction function. As the FSU and the ROW play a game à la Cournot on the brown energy market. The ROW increases its exports due to the shrink of FSU ones, as these exports are substitutes. Therefore, the coordination behaviour of the FSU is not profitable in terms of market share on the brown energy market if the green and the brown energy are strong substitutes.

6 Conclusion

This paper has set out to combine the Former Soviet Union strategic behaviour on the permits market with the interactions on the energy markets. We have shown that the EU energy mix consumption (brown or green) depends on the international permits price. Due to the FSU monopolistic behaviour on the permits market, the price for an additional emission raises, which in turn creates an incentive in the EU to increase the share of the green energy. In this context, the environmental efficiency is worsening as the abatements undertaken are costly. This paper also argues that a monopoly behaviour exerted by the FSU on the permits market leads to a sharp fall of the brown energy price if the green energy is a highly substitute with the brown. However, a coordinated FSU strategy on the brown and the permits markets is not sufficient to preserve the FSU market shares on the brown energy market relative to the Rest of the
World. In the coordinated strategy, the environmental efficiency is increased as the FSU fixes the permits at a lower level. Our contribution to the literature is to consider explicitly an international permits market interaction with an oligopolistic brown energy market. Various implications can thus be drawn from the previous results on the Kyoto protocol environmental efficiency. The model raises the issue on the EU-Russia relationship on the energy security supply with respect to the development of the renewable energy sources in Europe. This paper emphasizes also the debate on the allocation of the emission constraint in the FSU and the participation of the FSU domestic fossil fuel producers in the international permits market.
References


7 Appendix

Proof of proposition 1:

We have that:

\[
\begin{align*}
\frac{\partial x_{EU}}{\partial q} &= \frac{\partial z_{EU}^{x}}{\partial q} + \frac{\partial z_{EU}^{x}}{\partial q} \frac{\partial e_{EU}^{x}}{\partial q} = \left( \frac{1}{\gamma_{b}} - EMRS_{x_{b}/x_{g}} \right) \frac{\partial e_{EU}^{x}}{\partial q} \\
\frac{\partial x_{EU}}{\partial q} &= \frac{\partial z_{EU}^{x}}{\partial q} + \frac{\partial z_{EU}^{x}}{\partial q} \frac{\partial e_{EU}^{x}}{\partial q} = \left( \frac{1}{\gamma_{g}} - \frac{1}{EMRS_{x_{b}/x_{g}}} \right) \frac{\partial e_{EU}^{x}}{\partial q}
\end{align*}
\]

Moreover,

\[
\begin{align*}
\frac{\partial x_{EU}}{\partial \epsilon_{FSU}^{x}} &= \frac{\partial z_{EU}^{x}}{\partial \epsilon_{FSU}^{x}} \frac{\partial e_{EU}^{x}}{\partial \epsilon_{FSU}^{x}} + \frac{\partial z_{EU}^{x}}{\partial \epsilon_{FSU}^{x}} \frac{\partial e_{EU}^{x}}{\partial \epsilon_{FSU}^{x}} = \frac{\partial x_{EU}}{\partial q} \frac{\partial q}{\partial \epsilon_{FSU}^{x}} = \left( \frac{1}{\gamma_{b}} - EMRS_{x_{b}/x_{g}} \right) \frac{\partial e_{EU}^{x}}{\partial q} \frac{\partial q}{\partial \epsilon_{FSU}^{x}}
\end{align*}
\]

As \( \frac{\partial e_{EU}^{x}}{\partial q} < 0 \) and \( \frac{\partial q}{\partial \epsilon_{FSU}^{x}} > 0 \), \( \frac{\partial x_{EU}}{\partial \epsilon_{FSU}^{x}} \) is negative and \( \frac{\partial x_{EU}}{\partial \epsilon_{FSU}^{x}} \) is positive whenever

\[
\frac{1}{\gamma_{b}} - EMRS_{x_{b}/x_{g}} \frac{1}{\gamma_{g}} > 0 \text{ that is } EMRS_{x_{b}/x_{g}} > \frac{\gamma_{b}}{\gamma_{g}} > 1. \text{ Thus If the green and the brown energy factors are strong substitutes (i.e. } EMRS_{x_{b}/x_{g}} > \frac{\gamma_{b}}{\gamma_{g}} > 1 \text{) then a permits price increase induces a reduction in the EU brown energy consumption in favor of green energy consumption.} \]

Proof of Proposition 2:

The level of emissions chosen by the FSU in the case of a coordinated monopoly behaviour on the emission permits market is such that:

\[
q^{MC} = \frac{\partial p_{b}}{\partial \epsilon_{FSU}^{x}} - \frac{\partial q}{\partial \epsilon_{FSU}^{x}} (e^{fsu} - \pi^{fsu}) - \frac{\partial A^{fsu}(e^{fsu})}{\partial \epsilon_{FSU}^{x}}
\]

The level of emissions chosen by the FSU in the case of a non-coordinated monopoly behaviour on the emission permits market is such that:

\[
q^{M} = \frac{\partial q}{\partial \epsilon_{FSU}^{x}} (e^{fsu} - \pi^{fsu}) - \frac{\partial A^{fsu}(e^{fsu})}{\partial \epsilon_{FSU}^{x}}
\]

(ii) and (iii): For each level of emissions, the sign of the difference \( q^{MC} - q^{M} \) depends on the sign of \( \frac{\partial p_{b}}{\partial \epsilon_{FSU}^{x}} = \frac{\partial p_{b}}{\partial \epsilon_{FSU}^{x}} \frac{\partial q}{\partial \epsilon_{FSU}^{x}} \). From the proof of proposition 1
we know the sign of $\frac{\partial x_b}{\partial q}$. Thus we have that if $EMRS > 1$ (i.e. if the products are strong substitutes) then $q^{MC} - q^{M} < 0$ implying that $(e^{fsu})^{MC} < (e^{fsu})^{M}$.

If $0 < EMRS < 1$ (i.e. if the energies are weak substitutes), we obtain the opposite result that is $q^{MC} - q^{M} > 0$ and $(e^{fsu})^{MC} > (e^{fsu})$.

**Proof of proposition 3:**

If the brown and the green inputs are strong substitutes (i.e. $EMRS > 1$) then the FSU market share on the brown energy market decreases to the benefit of the ROW. The reaction functions of the FSU and the ROW on the gas market in the coordinated case are given by equation (8) and (24). Assume that $x^{fsu}_{b} = x^{row}_{b}$ as it is the case for the FSU does not coordinate its positions. Thus, from equations (8) and (24) as the FSU and the ROW have the same marginal cost of extraction, this is a possible equilibrium only when $e^{fsu} = e^{fsu}$. If $e^{fsu} < e^{fsu}$ and the brown and the green are strong substitutes then equation (24) will be less than zero as long as $x^{fsu}_{b} = x^{row}_{b}$ and $\frac{\partial q}{\partial x_b} < 0$. Hence, equilibrium requires that $x^{fsu}_{b} < x^{row}_{b}$ when the FSU coordinates its strategic positions and the energies are strong substitutes. For weak energy substitutes, it is straightforward to show, using a similar reasoning, that $x^{fsu}_{b} > x^{row}_{b}$.

**Proof of proposition 4:**

We suppose that the green and the brown energy are strong substitutes. From equations (19) and (26) we have that the net marginal abatement cost of the FSU in the coordinated case is higher than its level in the monopoly case. Although the net marginal abatement costs are still not similar across countries in the coordinated monopoly, the deviation from the cost-minimizing solution is less important and the increase in the total compliance costs in the EU is lower. Thus, in term of environment cost-effectiveness, when the brown and the green
energy are strong substitutes, the FSU coordination of strategic positions on the brown energy and the permits price markets is preferable to the non-coordination as it results in a lower total cost of meeting the global environmental constraint imposed by the Kyoto protocol.