How much would the Kyoto Protocol cost to consumers?

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Abstract:

In recent decades there has been a growing interest in the consequences of globalization for environmental problems, especially for those generated by greenhouse gas emissions. This concern has been intensified in the last years since the five-year accounting period (2008-2012) of the Kyoto protocol is near to be accomplished. The numerous published papers related to this topic reveal that little attention has been paid to the macro-economic effects of this protocol. This paper starts from the assumption that industries incur extra costs per ton of emitted pollutants (e.g. CO_2 abatement costs, emission allowances in the EU Emissions Trading Scheme, environmental taxes, opportunity costs), which are necessary to reduce the present amount of pollution. It is further assumed that all producers fully pass these costs on to the buyers of their products. As a consequence, this will affect the value of consumption. This 'extra' cost to consumers can be viewed as a change in the consumption price index. The aim of this paper is to give some insights in the extra costs for consumers if Annex B countries had fulfilled the targets of the Kyoto protocol. Using the World Input-Output Tables of the WIOD project, this paper analyses different scenarios. The main results show that, in general, consumers might well be able to bear the economic costs of the Kyoto protocol.

Keywords: Price input-output model, World Input-Output Tables, cost of pollution

1. Introduction

In recent decades there has been a growing interest in the consequences of globalization for environmental problems, especially for those generated by greenhouse gas (GHG) emissions. This concern has been intensified in the last years since the five-year accounting period (2008-2012) of the Kyoto protocol is near to be accomplished.

Studies concerned with the analysis of the broader economic repercussions of adopting the Kyoto protocol are usually based on modelling the interaction between the environment, energy sectors, and the rest of the economy. Basically there are two broad approaches: the so-called bottom-up and top-down models. The bottom-up models accentuate the analysis on a detailed, technologically-based treatment of the energy system; whereas the top-down models stress a theoretically consistent description of the general economy. Regardless their differences, both mainly coincide with respect the emphasis on the energy system as the sector where all policy instruments or technology changes are applied. Weyant (1999) offers an interesting and comprehensive report on a comparative set of modelling analyses of the economic and energy sector impacts of the Kyoto protocol. And in-depth studies for some countries can be found in ICCF (2005).

However, the numerous published papers related to environmental emissions monitoring by the Kyoto protocol using input-output framework reveal that little attention has been paid to the macro-economic effects of this protocol within this approach. In this paper we would like to have some insights about what would have been the cost for final consumers (i.e. households) if Annex B countries had fulfilled their Kyoto emission targets. We assume that all industries, not only the energy sectors, incur extra cost per ton of emitted pollutants in order to reduce the present amount of pollution employing the current technology. These costs can be materialized differently; for instance, in form of CO_2 abatement costs, emission allowances in the European Union (EU) Emissions Trading Scheme (ETS), environmental taxes, or economic opportunity costs. We further assume that the costs of emissions will pass along to consumers in the form of higher prices for all goods and services. The consumers' purchasing power will reduced by the higher cost of the consumption. Ultimately, this "extra" cost to consumers can be viewed as a change in the value of the same purchased bundle. In this paper, various scenarios are analysed using an input-output price model and the World Input-Output Database (WIOD).

The remainder of the paper is as follows. Section 2 provides the methodology. Section 3 offers the database description and the assumptions to accommodate available data to the model. In Section 4 we analyse the results for different scenario settings. They show that in the most likely situation, i.e. if all Annex B countries would have ratified the protocol and fulfilled their respective binding emission ceilings, consumers might well be able to bear the economic costs of the Kyoto protocol. The important role that China could play would offer different outcomes, although the main idea would prevail. Finally, conclusions are presented in Section 5.

2. Methodology

The analytical framework used in this study is the price input-output model based on monetary input-output table as presented in Chapter 2 of Miller and Blair (2009). The standard input-output approach assumes that each industry produces a single good by means of combination of intermediate inputs and primary factors in fixed proportions. It also assumes that all production processes operate under constant returns to scale and, in consequence, the economic benefits of each sector are equal to zero. Hence, the value of output of any sector j must be equal to the value of its inputs. That is, for sector j the value of its production (or sales) x_j should equal the cost of production given by the cost of intermediate inputs z_{ij} plus the cost of primary inputs μ_g. So, let p_j be the price per unit of sector's j output, and π_g be the exogenous unit price of primary input g (for instance, wage per person-year, rents of land per hectare and per year, or return on capital per year), we can write the following accounting equation:[1]

$$p_j x_j = \sum_{i=1}^{n} p_i z_{ij} + \sum_{g=1}^{m} \pi_g \mu_{gj} \qquad (1)$$

Dividing this expression by x_j gives:

$$p_j = \sum_{i=1}^{n} p_i a_{ij} + \sum_{g=1}^{m} \pi_g u_{gj} \qquad (2)$$

Where a_{ij} and u_{gj} are the intermediate and primary input coefficients, respectively. This expression shows the price of one unit of output j as the unit cost of production, i.e., the price of one physical unit of product j equals the cost involved in producing that unit. In matrix notation, the set of equations yields:

$$\mathbf{p}' = \mathbf{p}'\mathbf{A} + \mathbf{v}' \qquad (3)$$

Where $\mathbf{v} = \boldsymbol{\pi}\mathbf{U}$ is a vector of primary cost per unit of output whose elements represent the total monetary value of all primary inputs required for unit of sector j's output.

Expression (3) leads to:

$$\mathbf{p}' = \mathbf{v}'(\mathbf{I} - \mathbf{A})^{-1} = \mathbf{v}'\mathbf{L} \qquad (4)$$

Where $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief matrix. Expression (4) indicates that product prices are proportional to costs of primary inputs. If data are obtained from a standard input-output table in monetary terms, the price of each product will be equal to 1. That is, the base year index price will be represented by the summation vector consisting of 1's $\mathbf{i}'$. This fact reflects that there is a unique unit of measurement, i.e.

[1] Matrices are indicated by bold, upright capital letters; vectors by bold, upright lower case letters; and scalars by italicized lower case letters. Vectors are columns by definition, so that row vectors are obtained by transposition, indicated by a prime. A diagonal matrix with the elements of any vector on its main diagonal and all other entries equal to zero is indicated by a circumflex.

the amount that can be purchased for 1 monetary unit (let say American dollars $, Euros €, Japanese yens ¥, pound sterling £, etc.).

The price model presented above is generally used to measure the impact on prices throughout the economy of a change in the cost of primary inputs in one or more sectors.[2] However, this price model can also be applied to analyse the impact of new costs. Imagine the situation that industries must incur extra costs per ton of emitted pollutants (e.g. CO2 abatement costs, emission allowances in EU-ETS, environmental taxes, opportunity cost, etc.), which would be necessary to reduce a certain amount of pollution. In such a case, the new price of one unit of output j will be:

$$\tilde{\mathbf{p}}' = \tilde{\mathbf{p}}'\mathbf{A} + \mathbf{v}' + \mathbf{d}' \qquad (5)$$

Where $\mathbf{d}$ is a vector of extra cost per unit of output. The difference between initial prices $\mathbf{p}$ and new prices $\tilde{\mathbf{p}}$ will determine the impact on prices of this extra cost, such that $\Delta\mathbf{p}' = \tilde{\mathbf{p}}' - \mathbf{p}' = (\Delta\mathbf{p})'\mathbf{A} + \mathbf{d}'$. Solving this expression the price increase will be:

$$\Delta\mathbf{p}' = \mathbf{d}'\mathbf{L} \qquad (6)$$

In this study, the extra cost has been computed as $\mathbf{d} = \tau\mathbf{e}$, where τ is the environmental cost and $\mathbf{e}$ is the vector of extra emission coefficients. In that case, however, the emissions considered to calculate coefficients in $\mathbf{e}$ are those emissions that had exceed the target fixed by the Kyoto protocol ($\mathbf{w}$) to each country, such that: $\mathbf{e} = \mathbf{w}'\hat{\mathbf{x}}^{-1}$.

The input-output price model defined above are “long run” or “supply” prices (Bulmer-Thomas, 1982). That is, the prices of products are defined without considering the interaction of final demand from households or final consumers. Moreover, in this model it is further assumed that all producers fully pass their costs on to the buyers and, hence, the consumer (the final buyer) will bear the extra cost fully. Since consumers will face higher prices for all goods and services, their

[2] This price model is called *cost-push input-output price model* (Oosterhaven, 1996 and Dietzenbacher, 1997).

consumers' purchasing power would be reduced. This "extra" cost to consumers can be measured as a change in the value of consumption defining, for instance, a Laspeyres type price index:

$$PI_L = \frac{\sum_{i=1}^{n} \tilde{p}_i c_i}{\sum_{i=1}^{n} p_i c_i} \qquad (7)$$

Where c_i is quantity of good i purchased by consumers in the base year, p_i is the initial price of good i in the base year (i.e. the price without the extra cost), and $\tilde{p}_i$ is the new price of good i including the extra cost. This Laspayres price index compares the value of the bundle of base year using new prices with the value of the same bundle using the base year or initial prices. So, a Laspeyres price index of 1 would state that the consumer can afford to buy the same bundle of goods he consumed before adding the extra cost.

3. Database and assumptions

In this study we used the information offered by the World Input-Output Database (WIOD). This database includes a worldwide time series of national input-output tables for 40 countries covering at least 80% of world GDP and 35 sectors. The national tables are fully linked through bilateral trade data, generating a full multi-country input-output table. The time series covers the period 1995-2009 and contains tables in current and constant international prices. In addition, the WIOD also includes socio-economic and environmental satellite accounts. Specifically, we used the so-called World Input-Output Table (WIOT) analytical at current prices and air emissions of the three main greenhouse gases (GHG) monitoring by the Kyoto protocol (i.e. CO_2, N_2O and CH_4). [3] The GHG emissions have been aggregated in kilotons (kton) of CO_2 equivalent in accordance with the global warming potential (GWP100) of each gas as established by the IPCC (1997). These conversion factors are 1 for CO_2, 21 for CH_4, and 310 for N_2O.

[3] Only emissions from sectors are considered; so, household emissions have been discarded.

Since the aim of this study is to know what would have happened if ratifier countries of the Kyoto protocol had paid a cost for the emissions that had exceed the own target,[4] we need to quantify the amount of these extra emissions for each country and to determine the corresponding cost. On the one hand, due to WIOD characteristics we took 1995 emissions as an approximation of the Kyoto base year 1990 for all countries, and 2006 and 2009 as two hypothetical years of actuation (before and after the current crisis crashed). Hence, if the country already fulfilled their Kyoto target in 2006 / 2009 or it is a non-Annex B country, the extra cost was 0. Otherwise, we applied a cost on the extra emission coefficients. These coefficients were calculated as the difference between emissions in 2006/2009 and emission target in 2012 divided by 2006/2009 output.

On the other hand, we determine the hypothetical cost that countries would have paid for its extra emissions. In that case, we set out two different scenarios. In Scenario 1 we considered the price of one European Union Allowance (EUA) in the EU-ETS as approximation to the "cost of CO_2 emissions". Then, taking the mean of monthly prices of the allowance price evolution in the EU-ETS for 2006 and 2009, we determine the cost per ton of CO_2 as 26.3 US$ and 20.1 US$, respectively.[5]. In Scenario 2, we consider the information from the IEA annual report that states that taking into account the emission reduction actions that are possible with technologies that either are available today or offer a high degree of certainly about their potential in a 2030 time horizon, the reduction of 1 kton of CO_2 will be at cost below 100 US$ per ton of CO_2 (IEA, 2009).

Additionally, for each scenario we considered various assumptions. The first assumption (I) reflects the present context, i.e. non-Annex B countries do not have any target. The second assumption (II) aims to reproduce a hypothetical situation in which China had the same target as USA, i.e. it should have reduced their emissions by 93 percent of the base year emissions. However, this scenario might be too harsh

[4] The different targets are presented in Table A in the Appendix of this paper. For more information about the Kyoto protocol and each country target see United Nations (1997), and the website from the Framework Convention on Climate Change http://unfccc.int/kyoto_protocol/items/2830.php.

[5] Source of allowance price evolution in the EU-ETS (2005-2012) European Climate Exchange (www.ecx.eu). The cost for 2006 agrees the study of Ellerman and Joskow (2008) and other studies that consider GHG abatement cost (IEA, 2009; McKinsey & Company, 2009; Russ et al., 2009)

on China since their emissions had almost double in the period 1995 – 2006 and just double from 1995 – 2009. Hence, in a third assumption (III) we postulate that China agreed to reduce the same amount of emissions as the USA did, which would have implied a target to China of 130. Finally, in the last assumption (IV) we considers all non-Annex B countries had the same target as USA (i.e. the above 93 guideline) besides the assumption III.

Figure 1 brings together the three scenarios and the four assumptions considered in this study. Notice that in all cases we assumed USA ratified the Kyoto protocol on February 2005.

Figure 1: Summary of the scenarios and assumptions considered

SCENARIO 1: *Environmental cost in 2006 \$26.34 ton/CO_2* *Environmental cost in 2009 \$20.07 ton/CO_2*	*SCENARIO 2:* *Environmental cost in 2006 \$100 ton/CO_2* *Environmental cost in 2009 \$100 ton/CO_2*

- I: Kyoto Targets only for Annex B countries
- II: China has had the same target as USA (i.e. 93)
- III: China had agreed to reduce the same amount of emissions that USA does (i.e. 130)
- IV: Assumption III + all non-Annex B countries have had the same target as USA (i.e. 93)

4. Results

Regardless the four different assumptions considered the two scenarios settings create a boundary cost: scenario 1 establish a kind of cost floor and scenario 2 a cost ceiling.[6] This section presents the price consumption indexes in the each situation.

[6] A third scenario has also been computed. In that case, we took into account the information that almost all the emissions reductions come at cost of 75.3 US$ per ton of CO_2 in the period to 2030 (McKinsey & Company, 2009). The results from this "medium cost" scenario are not included.

Table 1: Price consumption indexes in 2006

	SCENARIO 1: floor cost				*SCENARIO 2: ceiling cost*			
COUNTRY	*Ass. I*	*Ass. II*	*Ass. III*	*Ass. IV*	*Ass. I*	*Ass. II*	*Ass. III*	*Ass. IV*
AUS	1.0024	1.0032	1.0028	1.0037	1.0093	1.0122	1.0107	1.0139
AUT	1.0012	1.0016	1.0014	1.0020	1.0045	1.0061	1.0053	1.0078
BEL	1.0005	1.0010	1.0007	1.0020	1.0019	1.0037	1.0028	1.0075
BGR	1.0003	1.0008	1.0006	1.0017	1.0012	1.0031	1.0022	1.0065
BRA	1.0001	1.0003	1.0002	1.0068	1.0003	1.0010	1.0006	1.0258
CAN	1.0016	1.0022	1.0019	1.0025	1.0061	1.0084	1.0072	1.0095
CHN	1.0001	1.0230	1.0118	1.0127	1.0005	1.0873	1.0448	1.0482
CYP	1.0002	1.0006	1.0004	1.0012	1.0009	1.0023	1.0016	1.0047
CZE	1.0017	1.0023	1.0020	1.0027	1.0065	1.0086	1.0076	1.0104
DEU	1.0011	1.0015	1.0013	1.0020	1.0040	1.0057	1.0049	1.0075
DNK	1.0023	1.0027	1.0025	1.0033	1.0088	1.0103	1.0096	1.0125
ESP	1.0010	1.0014	1.0012	1.0019	1.0036	1.0053	1.0045	1.0073
EST	1.0006	1.0012	1.0009	1.0020	1.0023	1.0047	1.0035	1.0076
FIN	1.0018	1.0022	1.0020	1.0026	1.0068	1.0084	1.0076	1.0099
FRA	1.0002	1.0005	1.0004	1.0010	1.0008	1.0020	1.0014	1.0037
GBR	1.0005	1.0009	1.0007	1.0014	1.0019	1.0034	1.0027	1.0053
GRC	1.0002	1.0005	1.0003	1.0010	1.0008	1.0017	1.0013	1.0037
HUN	1.0009	1.0013	1.0011	1.0017	1.0034	1.0050	1.0042	1.0066
IDN	1.0002	1.0008	1.0005	1.0192	1.0007	1.0029	1.0018	1.0728
IND	1.0001	1.0005	1.0003	1.0181	1.0003	1.0018	1.0011	1.0686
IRL	1.0003	1.0008	1.0005	1.0011	1.0011	1.0029	1.0020	1.0042
ITA	1.0008	1.0011	1.0010	1.0016	1.0030	1.0042	1.0036	1.0063
JPN	1.0004	1.0010	1.0007	1.0013	1.0017	1.0038	1.0028	1.0048
KOR	1.0002	1.0011	1.0007	1.0048	1.0006	1.0042	1.0025	1.0181
LTU	1.0028	1.0032	1.0030	1.0040	1.0106	1.0121	1.0114	1.0154
LUX	1.0004	1.0009	1.0007	1.0012	1.0013	1.0036	1.0025	1.0046
LVA	1.0006	1.0008	1.0007	1.0015	1.0022	1.0032	1.0027	1.0056
MEX	1.0002	1.0005	1.0004	1.0043	1.0008	1.0021	1.0015	1.0163
MLT	1.0004	1.0017	1.0011	1.0020	1.0016	1.0064	1.0041	1.0078
NLD	1.0006	1.0012	1.0009	1.0019	1.0021	1.0046	1.0034	1.0074
POL	1.0003	1.0007	1.0005	1.0011	1.0013	1.0028	1.0020	1.0043
PRT	1.0003	1.0005	1.0004	1.0011	1.0012	1.0019	1.0016	1.0043
ROM	1.0003	1.0007	1.0005	1.0012	1.0011	1.0025	1.0018	1.0047
RUS	1.0022	1.0028	1.0025	1.0035	1.0083	1.0108	1.0096	1.0132
SVK	1.0009	1.0014	1.0011	1.0022	1.0033	1.0051	1.0042	1.0085
SVN	1.0023	1.0025	1.0024	1.0034	1.0087	1.0096	1.0092	1.0127
SWE	1.0005	1.0008	1.0007	1.0014	1.0018	1.0032	1.0025	1.0052
TUR	1.0002	1.0005	1.0003	1.0056	1.0006	1.0018	1.0012	1.0213
TWN	1.0002	1.0010	1.0006	1.0076	1.0009	1.0037	1.0023	1.0290
USA	1.0012	1.0015	1.0013	1.0018	1.0044	1.0058	1.0051	1.0069
RoW	1.0003	1.0011	1.0007	1.0087	1.0013	1.0042	1.0028	1.0329
AVERAGE	**1.0008**	**1.0018**	**1.0013**	**1.0037**	**1.0030**	**1.0069**	**1.0050**	**1.0140**

Source: Own calculations.
Note: For the meaning of the countries acronyms see Table A of the Appendix section.

In the most likely circumstance, i.e. if ratifier countries of the Kyoto protocol had paid an environmental cost for the emissions that had exceed their targets (assumption I), the consumer would have face a world price average increase between 0.08% and 0.30% according to our lower and upper scenarios in 2006 (see Table 1). In both cases the maximum price increase would correspond to Lithuania (0.28% in scenario 1 and 1.06% in scenario 2) and the minimum to Brazil (0.01% in scenario 1 and 0.03% in scenario 2).

However, the greatest concern is what would have been the cost that consumers had had to pay if China had agreed to face a target in the Kyoto protocol. Since China exports over the world this hypothetical situation would have meant a great difference to the previous results. But the results show that in the most costly setting for China (scenario 2.II with the maximum cost of \$100 ton/CO_2 and the greatest reduction with a Kyoto target of 93) the world price average would have increased less than 0.4%. Under scenario 1 (the minimum cost of \$26.34 ton/CO_2) the increase of world "inflation" would have been of 0.10% if the China had faced a target of 93 (assumption II) and 0.05% with a target of 130 (assumption III). After China (2.285 and 1.166), Malta (0.125 and 0.064), South Korea (0.095 and 0.048), and Australia (0.0876and 0.039) have been the countries that had suffered the highest increased of their price indexes. On the other extreme, would have been Brazil (0.018 and 0.009), Portugal (0.021 and 0.010), Greece (0.023 and 0.012), and Slovenia (0.023 and 0.012). The USA would have the position 29 of 41 (0.039 and 0.019), Table 3 illustrates the positions of other countries and the variation of price indexes in percentage can be checked in Table B of the Appendix.

Finally, in the most unlikely situation (assumption IV, i.e. if China would have agreed to reduce their emissions the same amount as USA did – 130 – and all the non-Annex B countries would have accepted the same target as USA – 93 –) the world price had increased in average 0.37% (if the cost was \$26.34 ton/CO_2) and 1.40% if the cost was \$100 ton/CO_2. The highest price consumption index would be for Indonesia (1.0192 and 1.0728) and the lowest to Greece (1.0010 and 1.0037).

Table 2: Price consumption indexes in 2009

	SCENARIO 1: floor cost				SCENARIO 2: ceiling cost			
COUNTRY	*Ass. I*	*Ass. II*	*Ass. III*	*Ass. IV*	*Ass. I*	*Ass. II*	*Ass. III*	*Ass. IV*
AUS	1.0012	1.0021	1.0018	1.0023	1.0062	1.0104	1.0090	1.0113
AUT	1.0004	1.0008	1.0006	1.0010	1.0018	1.0039	1.0032	1.0051
BEL	1.0001	1.0005	1.0004	1.0011	1.0005	1.0026	1.0019	1.0056
BGR	1.0001	1.0005	1.0003	1.0010	1.0003	1.0023	1.0016	1.0050
BRA	1.0000	1.0002	1.0002	1.0046	1.0001	1.0011	1.0008	1.0229
CAN	1.0009	1.0015	1.0013	1.0017	1.0045	1.0076	1.0066	1.0087
CHN	1.0000	1.0133	1.0089	1.0096	1.0002	1.0665	1.0445	1.0476
CYP	1.0000	1.0004	1.0003	1.0008	1.0002	1.0020	1.0014	1.0038
CZE	1.0001	1.0008	1.0005	1.0010	1.0004	1.0039	1.0027	1.0048
DEU	1.0003	1.0007	1.0006	1.0011	1.0013	1.0037	1.0029	1.0052
DNK	1.0011	1.0015	1.0013	1.0018	1.0054	1.0073	1.0066	1.0089
ESP	1.0000	1.0004	1.0003	1.0007	1.0001	1.0021	1.0015	1.0035
EST	1.0001	1.0006	1.0005	1.0011	1.0006	1.0032	1.0023	1.0056
FIN	1.0002	1.0006	1.0005	1.0009	1.0010	1.0030	1.0024	1.0042
FRA	1.0000	1.0004	1.0003	1.0006	1.0002	1.0020	1.0014	1.0032
GBR	1.0001	1.0005	1.0003	1.0008	1.0003	1.0025	1.0017	1.0041
GRC	1.0000	1.0003	1.0002	1.0006	1.0002	1.0015	1.0011	1.0030
HUN	1.0001	1.0005	1.0004	1.0008	1.0005	1.0026	1.0019	1.0039
IDN	1.0000	1.0006	1.0004	1.0115	1.0002	1.0031	1.0021	1.0573
IND	1.0000	1.0004	1.0003	1.0168	1.0001	1.0019	1.0013	1.0835
IRL	1.0001	1.0007	1.0005	1.0009	1.0004	1.0033	1.0023	1.0045
ITA	1.0000	1.0003	1.0002	1.0006	1.0002	1.0016	1.0011	1.0030
JPN	1.0000	1.0004	1.0003	1.0006	1.0001	1.0022	1.0015	1.0032
KOR	1.0000	1.0009	1.0006	1.0049	1.0002	1.0046	1.0031	1.0245
LTU	1.0007	1.0010	1.0009	1.0016	1.0035	1.0051	1.0046	1.0079
LUX	1.0001	1.0005	1.0003	1.0007	1.0004	1.0023	1.0017	1.0033
LVA	1.0001	1.0004	1.0003	1.0007	1.0007	1.0018	1.0014	1.0036
MEX	1.0001	1.0004	1.0003	1.0035	1.0003	1.0019	1.0014	1.0175
MLT	1.0001	1.0009	1.0006	1.0013	1.0004	1.0043	1.0030	1.0063
NLD	1.0002	1.0009	1.0006	1.0013	1.0009	1.0043	1.0032	1.0066
POL	1.0001	1.0005	1.0004	1.0007	1.0003	1.0026	1.0018	1.0037
PRT	1.0000	1.0003	1.0002	1.0006	1.0002	1.0013	1.0009	1.0030
ROM	1.0000	1.0003	1.0002	1.0007	1.0002	1.0017	1.0012	1.0035
RUS	1.0000	1.0008	1.0005	1.0013	1.0002	1.0039	1.0027	1.0065
SVK	1.0001	1.0006	1.0004	1.0011	1.0003	1.0030	1.0021	1.0054
SVN	1.0011	1.0015	1.0014	1.0021	1.0054	1.0074	1.0067	1.0105
SWE	1.0001	1.0005	1.0004	1.0008	1.0006	1.0026	1.0019	1.0042
TUR	1.0000	1.0003	1.0002	1.0040	1.0001	1.0016	1.0011	1.0197
TWN	1.0000	1.0007	1.0005	1.0051	1.0002	1.0034	1.0024	1.0256
USA	1.0003	1.0006	1.0005	1.0007	1.0013	1.0029	1.0024	1.0037
RoW	1.0001	1.0009	1.0007	1.0057	1.0004	1.0047	1.0033	1.0283
AVERAGE	**1.0002**	**1.0010**	**1.0007**	**1.0024**	**1.0010**	**1.0049**	**1.0036**	**1.0120**

Source: Own calculations.
Note: For the meaning of the countries acronyms see Table A of the Appendix section.

Table 2 shows the price consumption indexes for 2009. The results from this year would be relevant since 2009 is in the five-year accounting period (2008-2012) of the Kyoto protocol. The smaller "inflations" in 2009 reveal two important features. On the one hand, the EUA price crash from July 2008 that reached a minimum price of 8€ ton/CO_2 in the spring of 2009. And on the other hand, the unexpected reduction of emissions in most industrialised countries caused by negative economic growth rates because of the current economic crisis. In fact, in 2006 13 of 31 countries have accomplished their commitment within the Kyoto protocol. Only three years later these countries were 22 of 31. Of course, the intensity of the economic crisis has not affected all the countries equally, and although almost all industrialised countries have reduced their emissions there are other countries that have continued increasing their GHG emissions.

Since results in scenario 2 have been affected only by the second circumstance, the comparison between 2006 and 2009 would gather not only variations of international trade relationships but also the different emission levels in each country. Then, comparing scenario 2.I in both years we see that in 2009 average world price would have increased but 0.20% less than in 2006. The minimum "inflation" would have also corresponded to Brazil (1.0001) and the maximum to Australia (1.0062). If China had agreed the Kyoto protocol (either with the 93 or 130 commitments, i.e. scenarios 2.II and 2.III) the average world inflation would also decrease (0.20% and 0.14%, respectively). In both cases the maximum price consumption index would have corresponded to China and the minimum to Brazil. However, while China would have supported lower price indexes than in 2006 (1.91% and 0.03% fewer), Brazil would have faced higher inflations (0.01% in both assumptions). Finally, comparing scenario 2.IV in 2009 with 2006 the average world price index was 1.0120 (a 0.20% less than in 2006). In 2009 the maximum index would have been 1.0835 (a 1% higher than the maximum price index in the same scenario in 2006) and it would have corresponded to Indonesia; on the other side, the minimum of 1.0030 would have been a 0.07% lower than the same index in 2006, and it would have corresponded to Portugal.

Regarding the consequences on price increases of China entrance in Kyoto agreements, Table 3 shows the countries most affected would have been China, South Korea, the Rest of the World, and Australia; while the less affected are Brazil, Portugal, Latvia, and Greece (the variation of price indexes in percentage are in Table C of the Appendix).

Table 3: More and less affected countries if China would have agreed the Kyoto protocol under assumption II or III

Position in 2006	*COUNTRY*	*Position in 2009*	*COUNTRY*	*VARIATION OF POSTION 2006 - 2009*
1	CHN	1	CHN	=
2	MLT	2	KOR	+1
3	KOR	3	RoW	+2
4	AUS	4	AUS	=
5	RoW	5	MLT	-3
6	TWN	6	RUS	+2
7	NLD	7	CZE	+7
8	RUS	8	NLD	-1
9	EST	9	TWN	-3
10	CAN	10	CAN	=
11	LUX	11	IRL	+7
12	IDN	12	IDN	=
13	JPN	13	SVK	+4
14	CZE	14	EST	-5
15	BGR	15	DEU	+4
16	BEL	16	POL	+11
17	SVK	17	GBR	+8
18	IRL	18	BEL	-2
19	DEU	19	JPN	-6
20	FIN	20	HUN	+2
21	ESP	21	BGR	-6
22	HUN	22	AUT	+2
23	DNK	23	SVN	+15
24	AUT	24	FIN	-4
25	GBR	25	SWE	+5
26	IND	26	ESP	-5
27	POL	27	LUX	-16
28	LTU	28	DNK	-5
29	USA	29	FRA	+4
30	SWE	30	IND	-4
31	CYP	31	CYP	=
32	ROM	32	MEX	+3
33	FRA	33	USA	-4
34	ITA	34	LTU	-6
35	MEX	35	ROM	-3
36	TUR	36	TUR	=
37	LVA	37	ITA	-3
38	SVN	38	GRC	+1
39	GRC	39	LVA	-2
40	PRT	40	PRT	=
41	BRA	41	BRA	=

Source: Own calculations.
Note: For the meaning of the countries acronyms see Table A of the Appendix section.

5. Conclusions

This paper starts from the assumption that industries incur extra costs per ton of emitted pollutants (e.g. CO_2 abatement costs, emission allowances in the EU Emissions Trading Scheme, environmental taxes, opportunity costs), which would be necessary to reduce a certain amount of pollution. It is further assumed that all producers fully pass these costs on to the buyers of their products. As a consequence, this will affect the value of consumption. This 'extra' cost to consumers can be viewed as a change in the consumption price index.

In this paper we analysed what would have been the cost for final consumers if Annex B countries had fulfilled their Kyoto emission targets. Using the World Input-Output Tables of the WIOD project, this paper analyses different scenarios. The main results show that in the most likely situation, i.e. if all Annex B countries would have ratified the protocol and fulfilled their respective binding emission ceilings, consumers might well be able to bear the economic costs of the Kyoto protocol. However, different results have been obtained from other hypothetical situations exhibiting the important role played by China as it has been reflected in the strained negotiations.

Notwithstanding, these outcomes have to be taken with extremely caution and always as an approximation of what would have been the real situation. Due to the characteristics of the WIOD, neither the base year (1995) nor the year of action (2006 and 2009) coincide with the reality (1990 and 2012, respectively). This fact would be relevant for the latter since the economic crisis started in 2008 have had important influenced on the emission levels as the 2009 results show.

References

Bulmer-Thomas, V. (1982) *Input-Output Analysis in Developing countries: sources, methods and applications,* Chichester [etc.]: John Wiley & Sons.

Dietzenbacher, E. (1997) "In Vindication of the Ghosh Model: A Reinterpretation as a Price Model", *Journal of Regional Science,* 37, 629-651.

Ellerman, A.D., P.L Joskow (2008) "The European Union's Emissions Trading System in perspective", document prepared for the Pew Center on Glogal Climate Change, Cambridge, US: Massachusetts Institute of Technology, available at http://www.pewclimate.org/docUploads/EU-ETS-In-Perspective-Report.pdf

ICCF, The International Council for Capital Formation (2005) Reports on the Economic Cost of the Kyoto Protocol to Italy, Spain and the UK, Brussels: ICCF, available at http://www.iccfglobal.org/research/climate/index.html

IEA, International Energy Agency (2009) "World Energy Outlook 2009", Paris: OCDE, available at http://www.worldenergyoutlook.org/

IPCC (1997) Revised 1996 IPCC Guidelines for national greenhouse gas inventories, 3 volumes, London: Intergovernmental Panel on Climate Change, available at http://www.ipcc-nggip.iges.or.jp/

McKinsey & Company (2009) "Pathways to a Low-Carbon Economy. Version 2 of the Global Greenhouse Gas Abatement Cost Curve", McKinsey Solutions, available at https://solutions.mckinsey.com/ClimateDesk/default.aspx

Miller, R.E., P.D. Blair (2009) *Input-Output Analysis. Foundations and Extensions.* 2nd edition. Cambridge [etc]: Cambridge University Press.

Oosterhaven, J. (1996) "Leontief versus Ghoshian Price and Quantity Model", *Southern Economic Journal*, 62, 750-759.

Russ, P., J.C. Ciscar, B. Saveyn, A. Soria, L. Szábó, T. van Ierland, D. van Regemorter, R. Virdis (2009) "Economic Assessment of Post-2012 Global Climate Policies. Analysis of Greenhouse Gas Emission Reduction Scenarios with the POLES and GEM-E3 models", EUR 23768 EN-2099, Insitute for Prospective Technological Studies, Joint Research Centre, European Commission, Luxembourg: Office for Official Publications of the European Communities.

United Nations (1997) Kyoto Protocol to the United Nations Framework Convention on Climate Change, 10 December 1997, (FCCC/CP/L.7/Add.1).

Weyant, J. (Eds) (1999) "The Costs of the Kyoto Protocol: A Multi-Model Evaluation", *The Energy Journal*, Special Issue, May 1999, 390 pp.

Appendix

Table A: List of countries and corresponding Kyoto targets

	COUNTRY	TARGET	NOTES
AUS	Australia	108	
AUT	Austria	87	(1)
BEL	Belgium	92.5	(1)
BGR	Bulgaria	92	(2)
BRA	Brazil	--	(3)
CAN	Canada	94	
CHN	China	--	(3)
CYP	Cyprus	--	(2)
CZE	Czech Republic	92	(2)
DEU	Germany	79	(1)
DNK	Denmark	79	(1)
ESP	Spain	115	(1)
EST	Estonia	92	(2)
FIN	Finland	97.4	(1)
FRA	France	98.1	(1)
GBR	United Kingdom	87.5	(1)
GRC	Greece	125	(1)
HUN	Hungary	94	(2)
IDN	Indonesia	--	(3)
IND	India	--	(3)
IRL	Ireland	113	(1)
ITA	Italy	93.5	(1)
JPN	Japan	94	
KOR	South Korea	--	(3)
LTU	Lithuania	92	(2)
LUX	Luxembourg	72	(1)
LVA	Latvia	92	(2)
MEX	Mexico	--	(3)
MLT	Malta	--	(2)
NLD	Netherlands	94	(1)
POL	Poland	94	(2)
PRT	Portugal	127	(1)
ROM	Romania	92	(2)
RUS	Russia	100	
SVK	Slovak Republic	92	(2)
SVN	Slovenia	92	(2)
SWE	Sweden	104	(1)
TUR	Turkey	--	
TWN	Taiwan	--	(3)
USA	United States	93	Not ratified in 2005
RoW	Rest of the World	--	(3)

Source: United Nations, Framework Convention on Climate Change. Information available at http://unfccc.int/kyoto_protocol/items/2830.php

Notes: (1) European Union 15: they have a global target of 92.

(2) European Union: they enter in the EU later than 2004 and 2007; they have their own Kyoto targets.

(3) Non-Annex B countries.

Table B: Variation of price consumption index if China would have agreed the Kyoto protocol under assumption II or III in 2006

	SCENARIO 1					SCENARIO 2				
COUNTRY	Ass. I	Ass. II	Δ%	Ass. III	Δ%	Ass. I	Ass. II	Δ%	Ass. III	Δ%
AUS	1,0024	1,0032	0,076	1,0028	0,039	1,0093	1,0122	0,288	1,0107	0,147
AUT	1,0012	1,0016	0,041	1,0014	0,021	1,0045	1,0061	0,153	1,0053	0,078
BEL	1,0005	1,0010	0,048	1,0007	0,025	1,0019	1,0037	0,183	1,0028	0,093
BGR	1,0003	1,0008	0,051	1,0006	0,026	1,0012	1,0031	0,192	1,0022	0,098
BRA	1,0001	1,0003	0,018	1,0002	0,009	1,0003	1,0010	0,067	1,0006	0,034
CAN	1,0016	1,0022	0,061	1,0019	0,031	1,0061	1,0084	0,229	1,0072	0,117
CHN	1,0001	1,0230	2,284	1,0118	1,165	1,0005	1,0873	8,668	1,0448	4,422
CYP	1,0002	1,0006	0,037	1,0004	0,019	1,0009	1,0023	0,139	1,0016	0,071
CZE	1,0017	1,0023	0,055	1,0020	0,028	1,0065	1,0086	0,208	1,0076	0,106
DEU	1,0011	1,0015	0,045	1,0013	0,023	1,0040	1,0057	0,171	1,0049	0,087
DNK	1,0023	1,0027	0,041	1,0025	0,021	1,0088	1,0103	0,154	1,0096	0,079
ESP	1,0010	1,0014	0,043	1,0012	0,022	1,0036	1,0053	0,162	1,0045	0,083
EST	1,0006	1,0012	0,063	1,0009	0,032	1,0023	1,0047	0,239	1,0035	0,122
FIN	1,0018	1,0022	0,044	1,0020	0,022	1,0068	1,0084	0,165	1,0076	0,084
FRA	1,0002	1,0005	0,034	1,0004	0,017	1,0008	1,0020	0,129	1,0014	0,066
GBR	1,0005	1,0009	0,040	1,0007	0,021	1,0019	1,0034	0,153	1,0027	0,078
GRC	1,0002	1,0005	0,023	1,0003	0,012	1,0008	1,0017	0,088	1,0013	0,045
HUN	1,0009	1,0013	0,042	1,0011	0,021	1,0034	1,0050	0,158	1,0042	0,081
IDN	1,0002	1,0008	0,058	1,0005	0,029	1,0007	1,0029	0,219	1,0018	0,112
IND	1,0001	1,0005	0,039	1,0003	0,020	1,0003	1,0018	0,150	1,0011	0,076
IRL	1,0003	1,0008	0,046	1,0005	0,024	1,0011	1,0029	0,176	1,0020	0,090
ITA	1,0008	1,0011	0,032	1,0010	0,017	1,0030	1,0042	0,123	1,0036	0,063
JPN	1,0004	1,0010	0,055	1,0007	0,028	1,0017	1,0038	0,210	1,0028	0,107
KOR	1,0002	1,0011	0,095	1,0007	0,048	1,0006	1,0042	0,360	1,0025	0,184
LTU	1,0028	1,0032	0,038	1,0030	0,020	1,0106	1,0121	0,145	1,0114	0,074
LUX	1,0004	1,0009	0,059	1,0007	0,030	1,0013	1,0036	0,225	1,0025	0,115
LVA	1,0006	1,0008	0,026	1,0007	0,013	1,0022	1,0032	0,097	1,0027	0,049
MEX	1,0002	1,0005	0,032	1,0004	0,016	1,0008	1,0021	0,122	1,0015	0,062
MLT	1,0004	1,0017	0,125	1,0011	0,064	1,0016	1,0064	0,476	1,0041	0,243
NLD	1,0006	1,0012	0,065	1,0009	0,033	1,0021	1,0046	0,247	1,0034	0,126
POL	1,0003	1,0007	0,039	1,0005	0,020	1,0013	1,0028	0,149	1,0020	0,076
PRT	1,0003	1,0005	0,020	1,0004	0,010	1,0012	1,0019	0,078	1,0016	0,040
ROM	1,0003	1,0007	0,036	1,0005	0,018	1,0011	1,0025	0,136	1,0018	0,069
RUS	1,0022	1,0028	0,064	1,0025	0,033	1,0083	1,0108	0,243	1,0096	0,124
SVK	1,0009	1,0014	0,048	1,0011	0,024	1,0033	1,0051	0,182	1,0042	0,093
SVN	1,0023	1,0025	0,023	1,0024	0,012	1,0087	1,0096	0,088	1,0092	0,045
SWE	1,0005	1,0008	0,038	1,0007	0,019	1,0018	1,0032	0,142	1,0025	0,073
TUR	1,0002	1,0005	0,032	1,0003	0,016	1,0006	1,0018	0,120	1,0012	0,061
TWN	1,0002	1,0010	0,075	1,0006	0,038	1,0009	1,0037	0,283	1,0023	0,144
USA	1,0012	1,0015	0,038	1,0013	0,019	1,0044	1,0058	0,144	1,0051	0,073
RoW	1,0003	1,0011	0,076	1,0007	0,039	1,0013	1,0042	0,289	1,0028	0,147

Source: Own calculations.
Note: For the meaning of the countries acronyms see Table A of the Appendix section.

Table C: Variation of price consumption index if China would have agreed the Kyoto protocol under assumption II or III in 2006

	SCENARIO 1					SCENARIO 2				
COUNTRY	Ass. I	Ass. II	∆%	Ass. III	∆%	Ass. I	Ass. II	∆%	Ass. III	∆%
AUS	1,0012	1,0021	0,085	1,0018	0,056	1,0062	1,0104	0,419	1,0090	0,280
AUT	1,0004	1,0008	0,040	1,0006	0,027	1,0018	1,0039	0,201	1,0032	0,134
BEL	1,0001	1,0005	0,043	1,0004	0,029	1,0005	1,0026	0,213	1,0019	0,142
BGR	1,0001	1,0005	0,041	1,0003	0,027	1,0003	1,0023	0,203	1,0016	0,135
BRA	1,0000	1,0002	0,020	1,0002	0,013	1,0001	1,0011	0,100	1,0008	0,067
CAN	1,0009	1,0015	0,064	1,0013	0,043	1,0045	1,0076	0,317	1,0066	0,212
CHN	1,0000	1,0133	1,330	1,0089	0,889	1,0002	1,0665	6,626	1,0445	4,427
CYP	1,0000	1,0004	0,035	1,0003	0,023	1,0002	1,0020	0,174	1,0014	0,117
CZE	1,0001	1,0008	0,070	1,0005	0,047	1,0004	1,0039	0,348	1,0027	0,232
DEU	1,0003	1,0007	0,049	1,0006	0,033	1,0013	1,0037	0,242	1,0029	0,162
DNK	1,0011	1,0015	0,037	1,0013	0,025	1,0054	1,0073	0,186	1,0066	0,124
ESP	1,0000	1,0004	0,039	1,0003	0,026	1,0001	1,0021	0,195	1,0015	0,130
EST	1,0001	1,0006	0,053	1,0005	0,035	1,0006	1,0032	0,263	1,0023	0,175
FIN	1,0002	1,0006	0,040	1,0005	0,027	1,0010	1,0030	0,198	1,0024	0,132
FRA	1,0000	1,0004	0,037	1,0003	0,025	1,0002	1,0020	0,185	1,0014	0,124
GBR	1,0001	1,0005	0,044	1,0003	0,030	1,0003	1,0025	0,220	1,0017	0,147
GRC	1,0000	1,0003	0,028	1,0002	0,018	1,0002	1,0015	0,137	1,0011	0,092
HUN	1,0001	1,0005	0,042	1,0004	0,028	1,0005	1,0026	0,207	1,0019	0,138
IDN	1,0000	1,0006	0,057	1,0004	0,038	1,0002	1,0031	0,286	1,0021	0,191
IND	1,0000	1,0004	0,036	1,0003	0,024	1,0001	1,0019	0,180	1,0013	0,120
IRL	1,0001	1,0007	0,059	1,0005	0,040	1,0004	1,0033	0,295	1,0023	0,197
ITA	1,0000	1,0003	0,028	1,0002	0,019	1,0002	1,0016	0,139	1,0011	0,093
JPN	1,0000	1,0004	0,042	1,0003	0,028	1,0001	1,0022	0,210	1,0015	0,140
KOR	1,0000	1,0009	0,087	1,0006	0,058	1,0002	1,0046	0,435	1,0031	0,291
LTU	1,0007	1,0010	0,031	1,0009	0,021	1,0035	1,0051	0,155	1,0046	0,104
LUX	1,0001	1,0005	0,038	1,0003	0,025	1,0004	1,0023	0,189	1,0017	0,126
LVA	1,0001	1,0004	0,023	1,0003	0,016	1,0007	1,0018	0,116	1,0014	0,078
MEX	1,0001	1,0004	0,033	1,0003	0,022	1,0003	1,0019	0,163	1,0014	0,109
MLT	1,0001	1,0009	0,078	1,0006	0,052	1,0004	1,0043	0,389	1,0030	0,260
NLD	1,0002	1,0009	0,068	1,0006	0,046	1,0009	1,0043	0,339	1,0032	0,227
POL	1,0001	1,0005	0,046	1,0004	0,031	1,0003	1,0026	0,231	1,0018	0,154
PRT	1,0000	1,0003	0,022	1,0002	0,015	1,0002	1,0013	0,111	1,0009	0,074
ROM	1,0000	1,0003	0,030	1,0002	0,020	1,0002	1,0017	0,150	1,0012	0,100
RUS	1,0000	1,0008	0,076	1,0005	0,051	1,0002	1,0039	0,378	1,0027	0,253
SVK	1,0001	1,0006	0,055	1,0004	0,037	1,0003	1,0030	0,273	1,0021	0,183
SVN	1,0011	1,0015	0,040	1,0014	0,027	1,0054	1,0074	0,200	1,0067	0,133
SWE	1,0001	1,0005	0,040	1,0004	0,026	1,0006	1,0026	0,197	1,0019	0,132
TUR	1,0000	1,0003	0,029	1,0002	0,020	1,0001	1,0016	0,147	1,0011	0,098
TWN	1,0000	1,0007	0,064	1,0005	0,043	1,0002	1,0034	0,319	1,0024	0,213
USA	1,0003	1,0006	0,032	1,0005	0,021	1,0013	1,0029	0,160	1,0024	0,107
RoW	1,0001	1,0009	0,086	1,0007	0,058	1,0004	1,0047	0,430	1,0033	0,288

Source: Own calculations.
Note: For the meaning of the countries acronyms see Table A of the Appendix section.