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What will happen to the producer prices for fossil fuels if Kyoto is implemented?☆

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Abstract

Implementation of the Kyoto commitments will result in lesser global fossil fuel consumption in 2010 than would occur in the absence of climate policy. The paper explores how the consumption change resulting from climate policy implementation could affect the producer prices of fossil fuels. The conclusion is that the price impact will be insignificant if the climate policy goals are established credibly and in the near future, for that will give rationally behaving fossil fuel producers ample time to adjust production capacity to the changed outlook for future demand. It is argued that as long as capacity develops in line with demand, prices should remain the same, irrespective of the speed and direction of demand change.

Keywords: Fossil fuel prices; Kyoto consumption constraints

1. Introduction

Implementation of the Kyoto-commitments involves a reduction of greenhouse gas emissions in the Annex I countries around 2010 by some 5% from the actual levels in 1990. CO_2 dominates the greenhouse gas emissions total, and most of the CO_2-emissions occur as a result of fossil fuel burning. Hence, restrictions on fossil fuel usage have to be a main component of climate policies that aim at reducing greenhouse gas emissions. In the predominantly market-oriented economies of Annex I countries, carbon taxes, or trade in emission rights, raising the consumer price of fossil fuels, and so suppressing their usage, are likely to be the key instruments in climate policy implementation.

Calibration of the carbon taxes to accomplish a given reduction in usage has to take account of the common assertion that the producer prices of fossil fuels will fall in consequence of declining demand. If a pre-set reduction in fossil usage is contingent on a particular consumer price level, then a fall in the producer price will require a corresponding increase in the carbon tax. Such calibration will be accomplished automatically through the price of emission permits in a climate policy based on trading a predetermined volume of permitted emissions. Even then, however, it is important to clarify what will happen to the prices received by producers of fossil fuels, for this will determine the emission permit price.

The purpose of the present paper is to explore the extent to which the 2010 producer prices (before taxes and levies) of coal, oil and gas are likely to deviate from business as usual (BAU) price forecasts, when a climate policy like that envisaged in the Kyoto agreement is carried out.

The issue under investigation is of importance not only to climate policy implementation. Another important consideration is the well-being of the fossil producing industries and fossil exporting countries. The resource rents reaped by these industries and countries will clearly be reduced when the quantity demanded declines. These rents will be reduced even more if, at the same time, the price is suppressed below what it would otherwise have been.

The analyses of fossil fuel prices to be carried out, will all start out from the notional global industry cost curve that slopes steeply upwards as full capacity utilization is reached. In theory, the price impact of a demand cut can be readily determined with the help of that curve, both under competitive conditions and under monopoly, so

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long as the curve remains stable. As will be apparent from the following sections, the issue is not that straightforward. In particular, the cost curve can be expected to stretch or shrink, as production capacity is changed over time.

The paper proceeds as follows. Section 2 summarizes the recent price performance for coal, oil and gas, and provides a few authoritative forecasts of prices until 2010 under BAU assumptions. Section 3 determines the base case quantitative dimensions of the demand change. Section 4 analyzes the plausible price implications of that case. In Section 5, I consider some alternative scenarios along with their price implications. Section 6 summarizes the findings and conclusions.

2. Fossil fuels: historical producer prices and price forecasts under BAU assumptions

Of the three fossil fuels, *oil* is the only one which is widely traded on an integrated international market, and where the price path is easy to map, because existing exchange quotations like Brent or WTI, have a truly global significance.

In *coal*, the issues are trickier, partly on account of the wide range of coal qualities, but in particular because high transport costs create a very substantial wedge between mine mouth or FOB prices, on the one hand, and customer gate or CIF prices, on the other. There is a thriving international market, with suppliers like Australia and South Africa shipping coal to all continents, and with a reasonably clear price record. But then, international coal trade accounts for less than 15% of world output (IEA, 1999), and the ability to switch supply between the domestic markets and the international one is deemed to be limited (private communication with Keith Welham of Rio Tinto). At the same time, the track of domestic price developments in many countries is not easy to obtain.

Transport costs are proportionally even higher for *gas* than for coal. As a result, three major, separate markets have developed, one around Europe, another in North America and a third, based on LNG, in Asia Pacific, with Japan, Korea and Taiwan as the main consumers. Trade between the markets has so far been insignificant, and there is little correspondence between them in terms of price levels and price shifts. The analysis of gas in Section 4 focuses on the European market.

Table 1 summarizes the recent actual price performance, along with price forecasts until 2010 formulated under BAU assumptions, prepared by the European Commission (EC) in 1999, and by the International Energy Agency (IEA) and the World Bank in 2000. For oil, a forecast made in 2000 by the US Energy Information Administration (EIA) is also displayed. Note that all the data refer to producer prices. Constant 1990 US dollars (obtained by using the World Bank G5 Manufactured Unit Value Index in US dollars as deflator) are employed throughout. The prices are given both per unit commonly used in each fossil fuel market, and, to facilitate cross-fuel comparison, I also transform the numbers into dollars per ton of oil equivalent (TOE).

The low World Bank series for *coal* is due to exclusion of international transport costs. *Oil* prices were temporarily elevated in 1990 in consequence of the Gulf War, and the forecasts are in all cases at lower levels. The forecasters use the same specification for European *gas*, and it is not clear why they come out with different historical numbers.

Even though the World Bank envisages a somewhat declining future price trend for all three materials, the close correspondence between the 1997 price level and expected future prices in all the forecasts is striking. This suggests that the forecasters believe (a) that depletion has no impact on price during the period under consideration, i.e. that the long run industry cost curve is flat, and (b) that the 1997 prices for coal and gas are around equilibrium, i.e. that production capacity is in balance with demand and the marginal project reaps a normal capital return, while the Middle East oil producers, representing a cartel that faces a competitive fringe, are content to use their market power to maintain the price at the level that prevailed in that year. I share these beliefs (Radetzki, 1996).

3. The quantitative dimensions of the demand change

In this section, I endeavour to establish the quantitative dimensions of a plausible climate policy stance for the global demand (and consequently supply) for the three fossil fuels. This is not an unambiguous undertaking. Tables 2 and 3 contain the results of my attempt. The numbers have been derived from several studies prepared in recent years by the EC and EIA (EC, 1999; EC, 2000; EIA, 1998, 2000). I have adjusted the numbers in a few instances to assure consistency, where such was lacking within or between the original documents. I have undertaken several simplifications and made my own assumptions, where necessary, to overcome existing ambiguities.

In both tables, the Annex I rich market economies have been subdivided into North America, Europe (EU15),[1] and Asia Pacific. These country groups all have clearly binding commitments to constrain emissions, subject to their ratification of the Kyoto agreement.

[1] The sources used have not provided separate statistics for Norway and Switzerland, and for simplicity, these two countries have been excluded from the analysis. Given their smallness, I believe that the exclusion does not have a perceptible impact on the results.

Table 1
Fossil fuel prices. Constant 1990 US Dollars

Forecast source	Specification	Actual		Forecast	
		1990	1997	2005	2010
Coal, $ per ton					
IEA, 2000	Imports to IEA, CIF	51.0	36.8	37.4	37.4
EU, 1999	Imports to EU	47.5	44.0		42.3
World Bank, 2000	US exports, FOB	41.7	33.6	29.7	28.1
Oil, $ per barrel					
IEA, 2000	Imports to IEA, CIF	21.4	16.0	16.5	16.5
EU, 1999	Brent	23.8	18.6		16.9
World Bank, 2000	Average Brent, Dubai, WTI	22.9	17.7	15.1	14.1
EIA, 2000	Imports to US, CIF	21.1	17.6	19.7	20.2
Natural gas, $ per mmBTU					
IEA, 2000	European borders, CIF	2.79	2.25	2.00	2.00
EU, 1999	European market	2.83	2.78		2.83
World Bank, 2000	European borders, CIF	2.55	2.53	2.26	2.04
Prices in $ per ton oil equivalent					
Coal					
IEA, 2000	Imports to IEA, CIF	76	55	56	56
EU, 1999	Imports to EU	71	66		63
World Bank, 2000	US exports, FOB	62	50	44	42
Oil					
IEA, 2000	Imports to IEA, CIF	157	117	121	121
EU, 1999	Brent	175	136		124
World Bank, 2000	Average Brent, Dubai, WTI	168	130	111	103
EIA, 2000	Imports to US, CIF	155	129	144	148
Natural gas					
IEA, 2000	European borders, CIF	109	88	78	78
EU, 1999	European market	111	109		111
World Bank, 2000	European borders, CIF	100	99	86	80

Table 2
Fossil burning emissions and Kyoto commitments

	Emissions (million ton C)					Kyoto change (%)	
	1990	1997	2010 BAU	2010 Kyoto	2010 Kyoto-BAU	From 2010 BAU	From 1990
USA and Canada	1472	1622	1947	1370	−577	−30	−7
EU15	868	865	899	799	−100	−11	−8
Japan, Australia, New Zealand	364	405	457	354	−103	−23	−3
Total of above	2704	2892	3303	2518	−780	−24	−7
Transition economies	1337	878	992	1310	+318	+32	−2
Rest of the World	1795	2405	3851	3851	0	0	+114
Total world	5836	6175	8146	7684	−462	−6	+32

The two tables also specify the transition economies of the FSU and Central and Eastern Europe, all members of Annex I, with specific commitments under the Kyoto agreement. These commitments, however, are clearly not binding for the FSU, which will not attain the allowable emissions permitted by the agreement under any plausible development scenario. In contrast, the commitments are likely to be binding for some of the economically more successful Central and East European countries, e.g. Czech Republic, Hungary and Poland. These countries may well have to take measures to reduce emissions if they are to comply with Kyoto. Even in these cases, however, the need for intervention is much laxer than in the rich Annex I group, because the economic implosion

Table 3
Fossil fuels and emissions in 2010. BAU compared with Kyoto compliance. An example

		Fuel consumption (MTOE)				Emissions (MTC)			
		Coal	Oil	Gas	Total	Coal	Oil	Gas	Total
USA and Canada	BAU	673	1358	844	2875	676	821	450	1947
	Kyoto	190	1086	971	2247	190	657	518	1365
	Kyoto/BAU	0.28	0.80	1.15	0.78	0.28	0.80	1.15	0.70
EU15	BAU	182	655	401	1238	190	472	237	899
	Kyoto	90	590	481	1161	90	425	284	799
	Kyoto/BAU	0.50	0.90	1.20	0.94	0.47	0.90	1.20	0.89
Japan, Austr, N Zealand	BAU	141	383	121	645	138	250	69	457
	Kyoto	70	306	145	521	70	200	84	354
	Kyoto/BAU	0.50	0.80	1.20	0.81	0.51	0.80	1.22	0.77
Sum of above	BAU	996	2396	1366	4758	1004	1543	756	3303
	Kyoto	350	1982	1597	3929	350	1282	886	2518
	Kyoto/BAU	0.35	0.82	1.17	0.83	0.35	0.83	1.17	0.76
Transition economies	BAU	270	370	786	1426	270	273	449	992
Rest of the world	BAU	1658	2059	1114	4831	1683	1503	665	3851
Total world	BAU	2909	4806	3218	10933	2957	3318	1870	8146
	Kyoto	2278	4411	3497	10186	2303	3058	2000	7361
	Kyoto/BAU	0.78	0.92	1.09	0.93	0.78	0.92	1.07	0.90
	1997 actual	2240	3747	2114	8100	2330	2643	1202	6175
	Kyoto/1997	1.02	1.18	1.65	1.26	0.99	1.16	1.66	1.19

in all former communist countries has greatly reduced their energy use and CO_2-emissions after 1990. I simplify the following analysis by regarding the FSU along with Central and Eastern Europe in aggregate, as a region without a binding Kyoto constraint.

The tables also specify the rest of the world, i.e. the developing countries, comprising nations that are not members of the Annex I group.

For the purpose of the ensuing fossil fuel market analysis, I have assumed that the commitments to reduce emissions, entered into at Kyoto, will be honored, and that the reduced levels will be attained by 2010. I have further assumed that the entire reduction will be accomplished through CO_2-emission reductions within the energy sector, and that the transition economies will not sell their 2010 unutilized excess of emissions permitted under Kyoto (hot air, 318 million tons of C, see Table 2).[2] The latter assumption clearly exaggerates the need to reduce fossil fuel burning. This exaggeration will be further discussed in Section 5.

Table 2 shows historical emissions for 1990 and 1997, forecast BAU emissions in 2010, the emission volumes in the latter year according to the Kyoto commitments, and the committed emission reductions. For the rich Annex I countries, these reductions amount to 780 million tons C, or 24% of BAU in 2010, but only 7% of actual emissions in 1990. The table also shows the transition economies' hot air, and the anticipated 115% increase of emissions between 1990 and 2010 in the rest of the world (from 1795 to 3851 million tons C) which undertook no commitments in Kyoto.

Table 3 details the BAU fossil fuel consumption in 2010 for the three rich Annex I country groups, and my own reasonable assumptions about the reduced consumption volumes of each fossil fuel that are needed for the mandated 24% emissions reduction from BAU (see Table 2). The corresponding emission levels are also shown.

Thus, I take it that the emission cuts in the rich Annex I countries will be accomplished through a combination of overall fossil fuel usage reduction (17% of BAU in 2010) and inter-fuel shifts away from coal and mainly in favor of gas. The assumed cuts in coal usage are particularly strong in North America (72%),[3] where BAU coal consumption represents a very high proportion

[2] With the exception of hot air, the existence or non-existence of emission permit trading has no consequence for my quantification exercise. Trading may, however, have an impact on the division of the restraint among the fossil fuels.

[3] EIA (1998) projects a 77.5% reduction in coal usage in the US in a scenario where US energy sector CO_2-emissions in 2010 are cut by 7% from 1990.

of total energy usage. For Europe and Far East OECD (except Korea), where coal initially represents a smaller share of the energy balance, the feasible cut is assumed to be smaller too. In both regions, the implementation of Kyoto is seen to reduce coal consumption in 2010 to half the BAU level.

Table 3 also shows BAU fossil fuel usage and emissions for the transition economies and the rest of the world, on the assumption (simplified a bit for the transition economies) that these two country groups' fossil fuel usage will remain unaffected by Kyoto.

The total world rows of Table 3 depict a fossil fuel usage decline by 7% and world emissions reduction by 10% due to Kyoto, as compared to BAU. Finally, the two bottom lines of the table compare the Kyoto requirements with the actual 1997 fossil fuel usage and CO_2-emissions.

The total world fossil fuel consumption numbers at the bottom of Table 3 provide some of the elements for the following analysis of fossil fuel markets. A comparison of consumption in 2010 with BAU on the one hand, and climate policy implementation as specified above, on the other, shows that Kyoto will reduce global coal usage by 22%, and oil usage by 8%, but raise the usage of gas by 9%. More relevant for my purposes, however, the table shows the Kyoto constrained global consumption in 2010 to be 2% above actual 1997 consumption in the case of coal, and 18% and 65% above the 1997 consumption in the case of oil and gas, respectively.

A full-fledged investigation of how the fossil fuel usage will change in the respective country groups would require detailed analysis of the competitiveness of each fuel in different market segments in each of the regions under review. It would also require analysis of how that competitiveness will change as a uniform carbon emissions levy is imposed. Such an analysis is beyond the realms of my work. Clearly, quite different results could plausibly emerge from more detailed investigations. Such is the case with Bartsch and Müller (2000), whose exercise with a complex global computable general equilibrium model yield the result that world usage of coal in 2010 under Kyoto will be 8% below BAU, and that oil and gas usage will work out at 3% and 6% below the unconstrained level. Despite their underlying analytical detail, these results are based on numerous assumptions, some of which appear heroic. For example, the authors attribute credence and stability to current policy statements (e.g. that Japan will implement the Kyoto agreement without international permits trade), and posit a fast emergence and commercialization of a carbon free backstop energy source. For these reasons, I assert that their conclusions are not necessarily more realistic than the ones I derive from qualitative considerations of stylized facts and industry knowledge. Nevertheless, Section 5 presents some alternative scenarios with regard to fossil fuel consumption reduction and market behavior, in order to demonstrate the robustness of my base case results concerning the price impact of Kyoto.

4. Fossil fuel market analysis: the base scenario

The question to be addressed in the present section is whether the slower demand growth for coal and oil due to Kyoto will result in lower supply costs. In the same vein, it is necessary to explore whether the faster demand growth for natural gas in Europe due to Kyoto will result in higher supply costs. The assumptions made and the results of calculations that I have performed above, all form part of the base scenario now under consideration. The preliminary answer to the question is that the price impact of Kyoto is likely to be small, provided that the volume change of climate policy is established credibly and in the near future. The main elements behind this assertion run as follows.

First, as is revealed by Table 1, the forecasters, *on average*, project virtually unchanged BAU prices between 1997 and 2010, despite envisaged global demand increases of about 30% for coal and oil, and more than 50% for gas. As noted, this must imply that capacity is initially in balance with demand, and that new capacity will be developed in parallel with the growing demand, assuring continued equilibrium and normal capital returns to investors in new capacity (monopolistic capital returns in the case of Middle East oil) at the unchanged price level. It follows that investments in new capacity between 1997 and 2010 will stretch the industry cost curve to the right, or from S_1 to S_2 in Fig. 1, to satisfy the shift in demand from D_1 to D_2, at unchanged prices, P_2. There is nothing extraordinary in this perception. Abstracting from shorter run fluctuations due to business cycles or temporarily misconceived capital investments, most primary commodity prices have been stagnant or slowly falling over long periods of time, irrespective of their long run rates of growth of demand (Barnett and Morse, 1963; Radetzki, 1990).

Second, and still given that the 1997 prices represent equilibrium, it is possible to run the events in the opposite direction, as would be the case in the event of a profound climate policy implementation. Demand will now decline, and supply will be curtailed in parallel as depreciated capacity is not replaced, to assure unchanged price levels. This is represented by a downward shift in demand from D_2 to D_1 in Fig. 1, with the industry cost curve moving left, from S_1 to S_3, and prices remaining at P_1.

Third, there is one important difference between capacity adjustments to shifting demand in the

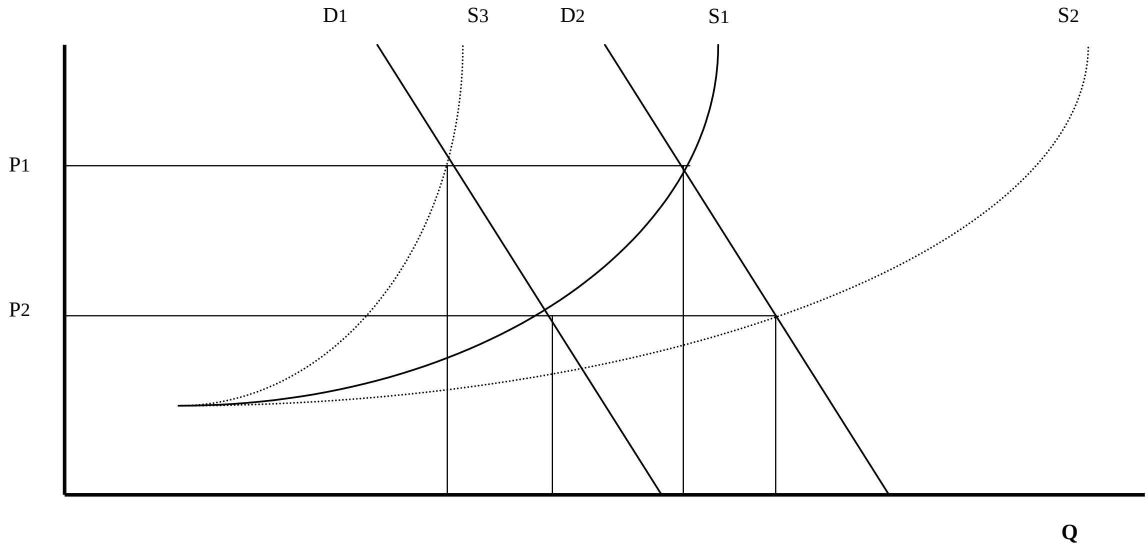

Fig. 1. Long run adjustments in supply curve to shifts in demand.

upward and downward direction. In principle, capacity can stay in balance with demand, irrespective of the speed of demand expansion, subject to a warning lag that is long enough to bring new capacity on line. In contrast, capacity will become excessive if the rate of demand decline exceeds capacity depreciation, and prices are likely to be pushed downwards in that event. Assuming an average project life of 25 yr, an existing capacity stock will automatically shrink by 4% per year, as old projects are retired.[4] Hence, even in the complete absence of investments, capacity will become excessive if demand reduces at an annual rate above 4%.

Fourth, it is evident from the numbers in Table 3 that world demand for any of the fossil fuels will not be reduced by anything like 4% per year, corresponding to more than 40% in total in the 1997–2010 period, in consequence of a policy resembling Kyoto (this is equally true for the results derived by Bartsch and Müller, quoted above). Hence, no problem needs to be encountered in avoiding excess capacity. My computations (bottom line of Table 3) show world demand in 2010 subject to Kyoto restrictions to be *higher* than in 1997 for all fossil fuels, including coal. With a normal 4% shrinkage in existing capacity due to a limited project life, substantial investments in new projects will be needed to maintain a balance between production capability and demand, while Kyoto is implemented. Hence, the BAU price forecasts contained in Table 1 appear to be plausible even if the Kyoto commitments are honored.

The assertion about unchanged prices relates to the global situation and does not take account of any geographic specifics or other peculiarities that characterize each of the fossil fuel markets. To obtain further insights, it is therefore necessary to disaggregate the analysis by fuel, and by geographical region, where appropriate. This is done in the following.

4.1. The coal market

International trade accounts for 15% of global coal output, and primarily on account of transport costs, there is limited fungibility between the international market and the domestic ones. In most domestic markets, and certainly in the international one, coal is supplied under competitive conditions. No monopolistic coordination is envisaged over the time horizon under review. In 1997, consumption in the world outside the rich Annex I countries exceeded 60% of the world total. Consumption in these regions is forecast to rise by more than one-third until 2010. This will clearly have a strong bearing on the development of global demand. Domestic supply in the world outside the rich Annex I countries will undoubtedly provide for a major share of the consumption growth, but part of the rising needs will plausibly be satisfied by increased imports.

It may be instructive to start the analysis by summarizing the overall changes in consumption between 1997 and 2010 under the Kyoto constraint.

[4] Private communications with Rio Tinto and Shell indicate that capacity depreciation may be greater than I assumed. David Humphreys at Rio Tinto states that this company regularly assesses new mineral projects (including coal and uranium) on the basis of a 20-yr life. And David Frowd from Shell International alludes that the annual global oil and gas capacity replacement needs may amount to as much as 8%. If, in fact, capacity depreciation is faster than I assume, then it follows that it will be even easier to adjust capacity to falling demand than suggested by the following analysis.

With the assumptions upon which Table 3 was constructed, the totals work out as follows in MTOE:

Global 1997 consumption	2240
Consumption reductions in rich Annex I countries	−560
Consumption increases in the rest of the world	+600
Global 2010 consumption with Kyoto constraints	2280

To provide a geographically disaggregated perspective to the required market adjustments, the reductions envisaged for each of the three rich Annex I groups are compared with the 1997 consumption, production and exports of each group. This is done in Table 4. I will now use the content of that table, along with my knowledge of the coal market to design a plausible example of how the adjustment could occur. The European Union probably offers the most straightforward prospects, so let me begin there.

Table 4 shows 1997 coal consumption in EU15 at 215 MTOE, satisfied by domestic production (113) and imports (102). Since I have posited the Kyoto constrained consumption in 2010 at 90 MTOE (Table 3), consumption will have to fall by 125 MTOE. Production in EU15, with Germany, the UK and Spain accounting for a dominant share of the total, is hopelessly uneconomic, and can be maintained only through huge public subsidies (Radetzki, 1995). A plausible policy stance would be to discontinue this subsidization, thereby eliminating virtually all coal production in the European Union. Such a policy would carry the double dividend of reducing the taxes that finance the subsidies, and of achieving a very substantial part of the Kyoto goal. Remaining adjustments in the EU15 coal market would involve a 12 MTOE reduction of imports in 2010. This volume is so small that by itself it could hardly make a dent to the international market for coal.

Adjustments in the Far Eastern rich Annex I group are not as straightforward. I provide separate 1997 data for Australia–New Zealand and Japan, given their very different coal market profiles. Most of Australia–NZ's output is exported, and roughly half of these exports end up in Japan, where they account for about half of total import needs. Since Japan is committed by Kyoto to reduce emissions by 6% from the 1990 level, while Australia's can increase by 8%, most of the downward adjustment in the region's coal consumption (68 MTOE) is bound to take place in Japan. Suppose that the cut in Japan is 50 MTOE, distributed among its foreign suppliers in proportion to the 1997 imports. This will reduce the Australia–NZ exports by 25 million tons. Australia–NZ will have to reduce output by an additional 18 MTOE, in response to its own consumption cut. Demand in 2010 for Australia–NZ coal would then be reduced by 43 MTOE, corresponding to 30% of its 1997 output. Spread across the 14 yr 1997–2010, the reduction works out at 2.7% per year, much below the annual 4% automatic depreciation of capacity, discussed earlier in the present section. The annual adjustment requirement in Australia–NZ can be subdivided between the domestic and export supplies, respectively. Supply to the domestic market will have to fall by 3.5% per year, while the need to adjust foreign trade works out at 2.3% per year.

Australia–NZ might lose additional exported quantities to the EU, but this loss could not be large, given its relatively small initial exports to Europe, and the limited West European adjustment needs, posited above. Also, such losses could well be compensated by export growth to other markets. I conclude on this evidence that an early credible commitment to implement the Kyoto agreement is unlikely to have any significant impact on the prices of Australia–NZ coal supply.

The adjustments in the US–Canadian domestic market are, by my assumptions, the most dramatic. The goal of a Kyoto-constrained coal consumption level in 2010 at 190 MTOE, implies a reduction in the combined domestic market of the two countries, of 365 MTOE, or two-thirds from the level actually recorded in 1997. This corresponds to about 8% per year, much higher than the automatic 4% capacity depreciation rate discussed above. With the simplistic analytical method that I apply, a large-scale excess capacity would temporarily emerge in the North American market, depressing prices substantially below their long run equilibrium levels. Exports from North America could be affected proportionately less than the domestic

Table 4
Adjustment requirements in coal in three rich Annex I regions. MTOE

		Consumption	Production	Exports
USA and Canada				
1997	USA	528	580	52
1997	Canada	27	43	16
1997	Total	555	623	68
2010 Kyoto	Total	190		
	Change	−365		
European Union				
1997	EU15	215	113	−102
2010 Kyoto	EU15	90		
	Change	−125		
Australia, New Zealand and Japan				
1997	Austr and NZ	48	145	97
1997	Japan	90	3	−87
1997	Total	138	148	10
2010 Kyoto	Total	70		
	Change	−68		

demand. Thus, the EIA (1998) projects only a 10% decline in US export from 1997 to 2010, under global Kyoto constraints such as I have assumed. But exports do not weigh heavily in the North American coal supply. Hence, the above conclusion about the emergence of a temporary excess capacity and about price declines in consequence, will not be altered by the milder adjustment needs in exported supply. The difficult adjustment to the Kyoto commitments likely to be faced by the US coal industry provides one explanation to the reluctance of the US administration to go along with the Kyoto agreement.

Further disaggregation of the North American coal market blurs the price outlook and might even put the conclusion about falling prices on its head. The EIA, for instance, found that while implementation of Kyoto would reduce domestic as well as export demand for US coal, there would nevertheless be a rise in prices, in comparison with the BAU case. Under Kyoto, coal would primarily lose markets in power generation, fed by low-cost mines in the US West. Coal supply from that region would therefore decline, in relative, and plausibly also in absolute, terms. The increased dominance of remaining coal provinces, primarily in the Appalachian, which extract coal at higher cost from underground mines, would result in higher average prices in the domestic market in the US (personal communication with Mary Hutzler of the EIA, Washington, DC, July 2000).

There remains the relatively simple task of assessing the impact of Kyoto on coal exporters other than those in Australia, New Zealand, Canada and the US, which have been dealt with above. World exports in 1997 amounted to some 350 MTOE, of which the four countries just listed accounted for 165 MTOE. Remaining exporters supplied some 186 MTOE. My above example asserted that Europe's Kyoto-constrained imports would be reduced by 12 MTOE between 1997 and 2010, and Japan's by 50 MTOE, and that half of Japan's reduction would relate to Australia–NZ coal. Remaining coal exporters would therefore suffer a reduction in demand of 37 MTOE (12 for Europe and 25 for Japan), or less, if account is taken of US–Canadian export shrinkage. The maximum reduction in the remaining coal exporters' market, thus amounts to about 20% over the 14-yr period under review, a proportion easily managed with automatic capacity depreciation.

The findings of this coal market analysis confirm the broader overview in the beginning of the present section: With the possible exception of the North American domestic market, implementation of Kyoto is unlikely to have a significant impact on coal prices, provided that the commitments are made early and in a credible manner.

4.2. The oil market

As noted in Section 2, the market for oil is internationally integrated. Transport costs constitute a low proportion of price, and the commodity is widely traded across continents. The main price quotations have a global relevance. Demand adjustments in a particular market will be absorbed globally, and price changes in one region (before taxes and levies) will have immediate and global repercussions. In distinction from the case of coal, therefore, there is no analytical need for geographical disaggregation.

The data of Table 3 reveal that world consumption, 3747 MT in 1997, will rise to 4806 MT in 2010 under BAU conditions. This amounts to an annual rise of 1.9%. Under Kyoto constraints, consumption in 2010 has been assumed to attain 4411 MT, an increase of 1.3% per year.

In my perception, the longer run oil price developments have been effectively determined for at least two decades, by the Middle East oil producers.[5] The Middle East is a geological anomaly insofar as oil is concerned. By far the largest and most economical oil resources are located there. This affords the producers in the region a very substantial leverage to steer prices in the direction they deem desirable. In the shorter run, the producers have controlled prices through output adjustments. A considerable restraint on investment and capacity expansion since at least the mid-1970s has been the key instrument for price control in the longer run.

Ever since the mid-1980s, the Middle East producers have apparently striven for a price range of between \$15 and \$20 per barrel (Brent equivalent), presumably because they felt this range was low enough to restrain the rate of capacity expansion elsewhere, and so would assure them of a large and stable market share. Given that their total production costs seldom exceed a few dollars, the price range has yielded huge profits. On this evidence, target pricing has been the major policy tool of the cartel.

Short run disturbances have clearly occurred, temporarily pushing the price out of the desired range. The Iraqi invasion of Kuwait in 1990, and the sharp decline in the export capability of the FSU in subsequent years, provide examples. The Middle East producers have regularly adjusted their own supply, to counter such disturbances. In some cases, the output decisions have been misguided in terms of their impact on price, but then they were soon corrected. Such was the case about the production increase late in 1997, which led to a price fall below \$10 at times, because the producers had failed to take account of the demand decline caused by the Asian crisis. They then overreacted in the opposite

[5] My views on this issue have been developed in Radetzki (1990) and Dienes et al. (1994).

direction by decisions to cut output in 1998 and 1999, when global industrial expansion was in full swing, so the price went up to very high levels in 2000. Subsequent production adjustments along with the worldwide economic recession in 2001 have suppressed the prices in the latter year.

The BAU oil price forecasts contained in Table 1 all project prices roughly within the $15–20 range. One can, therefore, subsume that the forecasters believe the policy of target pricing will continue and that the price band desired by the Middle East will remain unchanged. I concur with these views.[6]

The issue requiring resolution is whether implementation of Kyoto, reducing the annual global oil demand growth from 1.9% to 1.3%, will induce a change in the price goal that the Middle East producers wish to pursue. I see no convincing reason for this being so. History provides support for this view. The target price band appears to have remained unchanged, despite a sharp shift in the growth of oil consumption since 1985, from an annual average of 1.8% in the seven year period 1986–1992, to 1.1% during 1993–1999 (BPAmoco, 1995, 2000). I therefore assert that the price forecasts of Table 1 provide a reasonable representation of developments, both in the presence and absence of climate policy implementation.

4.3. The European market for natural gas

On account of the European focus of the research in which this paper forms part, the subject treatment is limited to the European gas market. For analytical purposes, I explore the impact of Kyoto on gas consumption in EU15, and the repercussions of this impact on the European suppliers.[7] Separation of Europe from the rest of the world is reasonable, given the insignificance of gas supply from other parts of the world into Europe. In 1999, gas consumption in EU15 was based on production within the area, supplemented by supplies from Norway, the FSU and Algeria. The isolation of this market is reflected by the fact that virtually all exports from the three countries in that year ended up in Europe, while the supply to Europe from elsewhere (Trinidad, Qatar, UAE and Nigeria), accounted for less than 1% of overall usage. While imports from these distant suppliers will undoubtedly expand over the coming years, the relative isolation of the European gas market is bound to persevere in the period under review. As in the past, gas prices in Europe will therefore move independent of what happens to prices in North America and the Far East, where the other major gas markets are located.

I have asserted above that the implementation of Kyoto will result in reduced 2010 demand for coal and oil, compared to the BAU outcome. The analysis has then explored how the reduced demand might impact on the prices of these fuels. In the case of gas, the problem is reversed: The measures to restrain CO_2-emissions are seen to lead to substitution of gas for coal and oil, and so to result in an increased use of gas. More precisely, under BAU conditions, gas consumption in EU15 is seen to increase from 302 MTOE in 1997 to 401 MTOE in 2010, or at a rate of 2.2% per year. Under Kyoto, gas consumption is projected to rise to 481 MTOE, i.e. to a level exceeding BAU by 80 MTOE. The annual rate of gas consumption increase works out at 3.7% in this case.

Will the accelerated consumption developments under Kyoto raise future prices above the BAU forecasts summarized in Table 1 above? I contend that the answer is negative. The resource wealth currently under exploitation in the territories from which Europe is being supplied, is extraordinarily large, and growing, so a very sizable demand expansion can be assured with no upward pressure on cost above current levels. Furthermore, despite impressive cost cutting productivity improvements in the past, there is still a huge untapped potential for further lowering the cost of gas (IEA, 1995).

The Yamal Peninsula in Northern Siberia contains massive gas reserves that could easily supply EU15 with twice or three times the current 70-odd MTOE per year, if only the market were there and pipeline capacity were expanded. And pipelines will be expanded as soon as this is motivated by demand. Current capacity to deliver Yamal gas to Western Europe has been established on the basis of prices averaging below $2.5 per mmBTU between 1987 and 1999, and with no clear prospect for substantial increase. If this price level provided adequate incentive for setting up capacity in the first place, then, clearly it should be sufficient for capacity expansion, since expansion typically carries lower costs than greenfield development.

The reserves in the North Sea on queue for development have also multiplied, and markets, not current and projected prices, have effectively capped the production increase. New provinces of gas are currently under development in the interior of Algeria, greatly expanding the ability of that country to supply Europe.

Russia, the North Sea and Algeria are expected to adequately cover Europe's rising gas needs until 2010 under the BAU scenario. They could easily cover the higher needs under the Kyoto scenario, and costs might

[6] After having tasted the sweetness of higher prices during 2000, but before having experienced the market loss that the defense of these prices will involve, the OPEC oil producers raised their publicized price goals to $25–30 (Brent equivalent). I deem this shift to be temporary.

[7] Consumption developments in the FSU and in Central and Eastern Europe are disregarded. The Kyoto agreement does not impose a binding constraint on the FSU. Kyoto may have an impact on gas consumption in Central and Eastern Europe, but, as argued before, this impact is likely to be small.

even decline, rather than rise in consequence, because of economies of scale in production and transport.

The Nigerian LNG facilities came into production in 2000, with Europe as the primary market outlet. They have been prompted by the stable historical prices and price prospects. Again, supplies to Europe depend on the development of the European market. They will be larger if implementation of Kyoto expands demand.

Further, large-scale supplies from Turkmenia, and later from Iran and the Middle East, too, await the development of Europe's gas demand, even though those from Iran and the Middle East, representing new ventures, with larger initial unit costs, might require higher prices than the ones currently forecast. But it is noteworthy that Turkmenia, desirous to sell gas to the EU, has been effectively hindered from doing so by the Russian pipeline monopoly. In 1989, Turkmenia supplied 75 MTOE within the FSU; by 1998, its output, but not production capacity, had shrunk to 11 MTOE, because of absent market access.

In conclusion, therefore, resources do not constitute a constraint to satisfying Europe's higher gas needs under Kyoto. And the cost of the additional supply does not motivate a change in the BAU price forecast.

In the 1970s, the oligopoly supplying gas to the EU, dominated by state owned agencies in the Netherlands, Norway, Russia and Algeria, had effectively tied the price of gas to the price of oil, and so reaped tremendous gas rents so long as the price of oil remained high. After the 1986 oil price collapse, these rents were sharply curtailed, and the average 1987–1999 price of some \$2.5 per mmBTU is probably a fair representation of the total cost of marginal supply. The growing number of suppliers (deliveries from the UK through the Interconnector; disintegration of the Norwegian state monopoly; new deliveries of LNG from Nigeria), the eagerness of producers to increase deliveries, and the legal changes that aim to sharpen competition in EU's gas market make it unlikely that sizable monopolistic gas rents would reemerge.

For the reasons spelled out, I reassert my claim that the gas price forecasts contained in Table 1, \$2.0–2.8 per mmBTU provide a reasonable picture of the future. They do so even in the event that gas demand accelerates in consequence of climate policy implementation.

5. Alternative scenarios and qualifications

The base scenario conclusions reveal that an early and credible decision to implement Kyoto is unlikely to have a significant impact on producer prices for fossil fuels. The one exception to this conclusion relates to coal in the US, where the envisaged sharp cut in consumption, due to climate policy, could lead to the emergence of excess capacity and lower prices than would occur with BAU. However, the base scenario is founded on a number of assumptions, some of which may turn out to be wrong. The present section tests the robustness of my conclusion by investigating alternative assumptions in a number of areas. The implications are spelled out one at a time and only at the global level. In my judgment, the alternatives in aggregate reinforce the base case conclusion about unchanged prices. The need for downward adjustment in fossil fuel consumption is likely to be smaller, when both the volume impact and the likelihood of each alternative assumption is taken into account.

5.1. Alternative paths of emissions reductions

As noted, the base case results are crucially dependent on an early and credible commitment by the Annex I countries effectively constrained by Kyoto, to implement the agreement.

One cannot preclude a situation where the seriousness of the Kyoto commitment remains in doubt for several more years, and where fossil fuel producers and others fail to make adjustments until very late in the present decade. A subsequent sudden implementation of the agreement will clearly result in excess capacity for coal and oil, with prices falling from P_1 to P_2 in Fig. 1, as demand is cut from D_2 to D_1, while the supply schedule, S_1 remains unchanged.[8] Fossil producers will clearly suffer from this outcome. A consequence likely to be of greater concern to the policy makers in rich Annex I countries, is that consumers dependent on a smoothly functioning energy market, will also endure severe pain from the sudden adjustment need. For this reason, I consider such a sudden implementation of Kyoto to be unlikely. The politicians will simply back off from their commitment, once they have considered the consequences in full. I assert that the Kyoto commitments will not be implemented without an extended period of adjustment.

A politically more likely evolution is a path of "muddle through", where credible decisions are taken late, and are watered down, to avoid adjustment pains. A multitude of "muddle through" alternatives can be imagined. For example, exemptions can be introduced for suffering parties in rich Annex I countries, or the implementation time can be extended. The essence of this case is that the emission cuts agreed to in Kyoto will not be reached in full by the prescribed time. While the likelihood for global excess capacity and falling prices is raised by the delay of definitive decisions, the dilution of the required cuts will facilitate adjustment, and so help avoiding a market imbalance. The ultimate impact on

[8] The price fall will have to be even greater to assure a downward adjustment in usage equal to the horizontal distance between D_2 and D_1.

fossil fuel prices, if any, will depend on the precise content of the "muddle through".

5.2. Excessive investment by frustrated coal producers

Even if the Kyoto commitments are entered into at an early date and leave no ambiguity, one cannot preclude the possibility that fossil fuel producers will fail in adjusting their investments to the emergent realities. The risk for this to occur is most serious in coal, where the greatest adjustments will be needed. In my base scenario, Kyoto involves a completely stagnant world coal demand between 1997 and 2010, instead of a growth by 2% per year under BAU (Table 3). It is conceivable that investors in coal mining, frustrated by the weakened prospects, will irrationally over-invest, thus creating over-capacity and suppressing price levels, despite full information about the weakened demand prospects. The extended gestation periods for investments in coal mining increase both the risk of such over-capacity to emerge, and the seriousness of its consequences. The impact of individual investment decisions which are collectively excessive, will be felt only several years later, when the new projects mature.

It is hard to put a probability on a global excess capacity in coal to emerge in consequence of climate policy implementation. The likelihood should have decreased in consequence of the recent consolidation of the international coal supply into a limited number of giant enterprises with a global vista and each anxious to keep track of its competitors' endeavors (Humphreys and Welham, 2000). Tendencies towards global over-investment should be easier to detect in the new coal industry setting.

5.3. A shift in the policy of the oil cartel

My base scenario posits that the objective pursued by the Middle East oil cartel ever since the large oil price fall of 1986, has been to maintain prices within a \$15–20 band, and that this policy will persevere even while Kyoto is implemented. The target price policies of the cartel could obviously change, as the Kyoto restrictions are put in force. With a lower growth of global oil demand, the Middle East producers might decide that their desire to maintain expanding sales volumes requires a lowering of the target price, or else they might shift towards an outright volume target. In both cases, the likely result will be a lower oil price than that projected by the forecasts in Table 1. Oil being the most important of the fossil fuels, repercussions on the coal and gas prices would probably follow.

I deem such a change in the cartel policies in consequence of Kyoto to be unlikely. As noted in the preceding section, pursuit of climate policy might reduce the 1997–2010 annual growth in global oil demand to 1.3%, from 1.9% under BAU. It was shown there that the cartel policies remained unchanged in the past 16 years, despite even larger shifts in the demand trend. Furthermore, as will be apparent from the following paragraphs, the downward adjustment in the consumption trend due to climate policy is likely to be less than predicated by the base scenario.

5.4. Hot air

Table 2 above noted that the transition economies' BAU emissions in 2010 will settle some 318 million tons of C below the level permitted under Kyoto (hot air). With a permissions trading system within the entire Annex I group, the transition economies could in principle sell this amount of permits to the countries which face binding Kyoto constraints, without undertaking any reduction at all of their own BAU emissions. The global emissions decline will shrink by two-fifths, or from 10% of BAU in 2010 (see Table 3) to only 6%, if hot air is employed in full for permissions trading. The burden of adjustment imposed on fossil fuel producers will be reduced by some 40% from the levels indicated in the base scenario, if permits trading based on hot air is allowed. Any downward pressure on producer prices will be correspondingly reduced.

In the base scenario, I assumed that hot air would not form part of the implementation of Kyoto. This in my view is the most probable outcome of the political negotiations in progress.

5.5. Carbon sequestration

Two processes are involved. The first is the uptake of carbon from the atmosphere by growing forests. The second is the permanent deposition of carbon dioxide from stationary emitters like power stations, e.g. in depleted oil and gas wells. Both reduce the net CO_2-emissions to the atmosphere at any given level of fossil fuel burning. Neither was taken into account in the base scenario. Judging from the outcome of the most recent round of climate negotiations in Bonn in July 2001 (Economist, 2001, July 21 and 28), both tools will be permitted, to some degree at least, when the committed emission cuts are implemented.

The potential and economics of carbon sequestration in forest sinks has recently been explored by Sedjo et al. (2001). Sedjo's analysis focuses on a century-long perspective. The findings suggest that relatively little sequestration is achievable within a decade, but then, the analysis of this relatively short run is incomplete. The numbers indicate that the cumulative additional global forest absorption of carbon between 2000 and 2010 will amount to some 7 million tons, if carbon emissions are priced at \$20 per ton in 2000, rising to \$25 in 2010, all compared to a zero emissions price. The cumulative additional absorption rises to 17 million tons with a static carbon emissions price at $100. One would have liked to know the additional absorption at an emissions price of $200, nearer to the assessed marginal costs of Kyoto implementation. The option of forest sinks must be significant and appear to be economically attractive, given the political pressure from the US, Canada and Australia, that this option should be fully permitted in the international climate agreement. I conclude that forest sinks will contribute at least marginally to the implementation of Kyoto, thus reducing, at least in some measure, the need to cut fossil fuel use.

Permanent deposition of CO_2 is not yet being practiced. A recent investigation relating to European power (Strömberg, 2001) reveals that more than 100 million tons of C per year, corresponding to one-half of total 1999 emissions from EU power production, could be potentially sequestered in this way at total costs of $180 per ton C, which is less than the cost of emission avoidance through expansion of power generation based on renewables like biomass, hydro, wind and solar. Though the author points out that large scale utilization of CO_2 deposition will occur only after 2010, it is interesting to note that the potential exceeds the overall EU commitment to reduce 2010 emissions below their BAU level (Table 2). The potential significance of deposition in overall climate policy is likely to be of similar magnitude in Annex I North America and Asia Pacific.

Even though the implementation rules for the Kyoto agreement remain to be fully defined, there is little doubt that both forest sinks and deposition of CO_2 will contribute significantly towards satisfying the 2010 commitments in the rich Annex I regions. This will permit a higher fossil fuel consumption than indicated in Table 3.

5.6. Reduced emissions of other greenhouse gases

CO_2 accounts for less than two thirds of the man-made impact on climate. Other important sources to global warming comprise methane and black carbon (Climate Change Science, 2001). It has been suggested recently (Hansen et al., 2000) that the strong emphasis on reduced CO_2 emissions in global climate policy approaches may be misguided. Reduction of methane emissions and removal of black soot appear to be more cost effective for climate stabilization over considerable ranges. Furthermore, greater focus on black carbon elimination would have the side benefit of improved health in densely populated poor countries, because such policy would improve air quality. A redirection of climate policy towards non-CO_2 sources of climate change would obviously greatly reduce the need to cut fossil fuel consumption for the purpose of achieving the Kyoto targets.

6. Conclusions

Using data from the Energy Information Administration, the European Commission and the International Energy Agency, I have established the quantitative dimensions of world fossil fuel use until 2010 under BAU conditions, on the one hand, and with implementation of the commitments to reduce greenhouse gas emissions, agreed to in Kyoto in 1997, on the other. Only the rich Annex I countries are effectively constrained by the Kyoto agreement, so the consumption adjustments are limited to this country group. The calculations suggest that world fossil fuel consumption in 2010, measured in oil equivalents, will be 7% lower under the Kyoto regime than with BAU, if climate policy relies entirely on reducing CO_2 emissions from fossil fuel burning. Consumption of coal will then be 22% lower, that of oil 8% lower, but consumption of gas will be 9% higher with the Kyoto constraints than in a BAU world.

The three agencies and the World Bank have prepared forecasts of fossil fuel prices until 2010, assuming BAU. All four project outcomes within a narrow range, and quite similar to the price levels in the recent past. This suggests that the forecasters believe current prices to be close to long run equilibrium. I explore how the predicted price levels (before any taxes or levies) may change in consequence of the demand shifts arising from climate policy.

While implementation of Kyoto will result in significantly lower world demand for coal and oil in 2010 than under BAU, that demand will nevertheless be 2% higher than in 1997 in the case of coal, and 18% higher for oil. In the case of gas, 2010 demand with Kyoto will be 65% higher than in 1997. If the current prices are close to long run equilibrium, then new capacity can be brought on line at roughly the present price level. Obversely, since production capacity automatically depreciates by some 4% per year in the absence of new investments, the supply capability can shrink at the same rate, and yet remain in equlibrium, with unchanged prices. My conclusion is therefore that Kyoto need not have any significant impact on fossil fuel price levels, provided that the volume impact of climate policy on fossil fuel demand is established firmly and believably in the near future.

Fossil fuel prices may fall if a credible decision to implement Kyoto is taken late, requiring very speedy adjustments in consumption, or if exuberant producers over-invest and create excess capacity. On the other hand, the conclusion about stable prices is reinforced when carbon sequestration in forest sinks or through permanent deposition, and reductions in other greenhouse gas emissions are added to the climate policy tools, for that will reduce the need to restrain fossil fuel usage.

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