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MODELLING THE IMPACT ODELLING THE IMPACT OF THE OIL PRODUCTS' MARKET EVOLUTION ON THE CO2 EMISSIONS OF THE EUROPEAN REFINERIES

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Overview

Diesel cars dominate new vehicle registrations in most European countries. Since the late 1990's, diesel demand has been rising by an average of 4 % per year and motor gasoline demand has decreased by 2 % over the past five years (Houdek, 2005). These trends are anticipated to continue in the future. Despite the "gasoline structure" of most of the European refineries, their primary focus at this time is to boost the production of middle distillates (especially diesel) while reducing gasoline output or keeping it stable. This imbalance is driving a significant increase in global trade flows for refined products and blend stocks. Imports from Russia and Central Europe are helping to fill the Western European diesel supply gap. Thanks to its gasoline advantage (lowest gasoline marginal cost), Europe equilibrates its oil product's trade by shipping its excess gasoline across the Atlantic to the United States.

This imbalanced supply-and-demand market is worsen with the tightening of product specifications required by European Union legislation. For instance, the gasoline and "on-road" diesel sulfur content is reduced to 50 ppm in 2005 and will be reduced to 10 ppm in 2009. A review of the European Union diesel specifications is also scheduled for 2006. All these evolutions would significantly increase the refineries energy consumption and their CO2 emissions. At the same time and under the terms of the 1997 Kyoto Protocol, European refineries are engaged to implement effective ways to reduce their carbon dioxide emissions. Under the proposed scheme, they should pay a fine for every ton of CO2 exceeding their annual emission quotas.

This paper follows a twofold objective. Firstly, it aims to evaluate the impact of the paradoxical evolutions in the European oil market on the marginal cost of the refined products and the refineries' carbon dioxide emissions. Secondly, it provides an allocation methodology (Azapagic and Clift, 1998, 1999, and Babusiaux, 2003) to assess and compare the marginal contribution of each oil product to the refinery's total CO2 emissions. These marginal CO2 contributions correspond to the marginal damage in terms of CO2 associated with refined products and can serve as a basis for defining a Pigouvian tax. Under certain conditions that will be discussed, this assignment procedure provides a unique and relevant CO2 allocation pattern that can be used for both decision making and Life Cycle Assessment purposes (Tillman, 1999) in "Well to Wheel" studies.

Methods

A typical European refinery model based on linear programming (LP)1 is used to study several challenges in oil refining industry such as the increasing demand for middle distillates, the tightening of the oil product specifications and the limitation of carbon dioxide emissions. This mono-refinery LP model contains the end-to-end configuration of a typical Fluid Catalytic Cracking (FCC) refinery with a detailed representation of processing units, blending facilities, power and utilities (Saint-Antonin, 1998). Such a model describes complex interactions between different process units and is based on physical relations between crude oils, intermediate products, finished products and CO2 emissions of the refinery. In a cost-

[1] Developed by the French Petroleum Institute (IFP).

minimizing LP formulation the dual variables associated with the product demand constraints can be interpreted as their marginal costs. Besides, the marginal contribution of oil products to the refinery's CO2 emissions can be extracted from the final simplex matrix calculated at the optimal solution of the LP. Since the optimal solution was degenerate, we solved other auxiliary LP models, based on simplex method and interior point method (primal-dual barrier method with predictor corrector), to deal with the multiple optimal solution phenomena (Gal, 1986).

In the process of abstracting and simplifying a real system the model looses information and needs to be verified against actual behavior. Evaluation of the oil products' marginal cost and marginal CO2 contribution based on a LP that shows a wide divergence between its optimal solutions and the actual production and cost pattern of a typical refinery is unacceptable. Different calibrating criteria were tested to validate the model. Based on scenarii about the European oil product demand (in terms of quantities and specifications) and different environmental policies, some middle-term simulations are performed for 2010 to assess the impact of the oil products' market evolution on the marginal cost and marginal contribution of various oil products to the total refinery's CO2 emissions.

Results

Some of the general and technical results can be summarized as follows:

The new specifications required by the European Union legislation (especially the trend toward ultra-low sulfur) will reduce the refinery outputs and require major investments to upgrade the existing refineries. These investments should especially occur to increase the hydro-cracking and middle distillate desulphurization capacities.

Forcing a "gasoline structure" refinery (i.e., a FCC refinery) to boost its production of middle distillates while reducing its gasoline output, results in a higher marginal CO2 contribution associated with diesel as compared to gasoline. This conclusion becomes even worsen with the tightening of the fuels specifications. The same conclusion is true for the refined product marginal cots.

Unlike the predictable behavior of marginal production costs (dual variables of the LP) which increase gradually in function of output productions, the marginal CO2 contribution of refined products (substitution coefficients from the final simplex matrix) have an erratic behavior. Due to this unpredictable evolution, it is recommended to perform a parametric analysis to fully compare the evolution of the CO2 allocations of various oil products.

Degeneracy and multiple optimal solutions are the rule in empirical LP models and should not be neglected, as is usually the case. In a degenerate LP, the marginal production costs do not always correspond to the dual optimal variables. Further parametric analysis are necessary to distinguish the marginal costs from dual variables. Numerical examples are given to illustrate potential errors.

Conclusions

We have provided an analysis of the European oil market evolution for 2010. The study is based on a typical European refinery LP model and is in accordance with consensual assumptions about oil product demands and specifications. In addition, an LP-based allocation procedure is used to assess and compare the marginal contribution of each oil product to the refinery's total CO2 emissions. The major limitations of this methodological tool is explained.