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Swedish industry and Kyoto—An assessment of the effects of the European CO_2 emission trading system

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Abstract

We assess the effects on Swedish industry input demands and output of different climate policy scenarios connected to energy policy induced by the Kyoto protocol. We use a unique dataset containing firm-level data on outputs and inputs between 1991 and 2001 to estimate a factor demand model, which we use to simulate different policy scenarios. Sector-specific estimation suggests that the proposed quadratic profit function specification exhibits properties and robustness that are consistent with economic theory; that is, all own-price elasticities are negative and all output elasticities are positive. Furthermore, the elasticities show that the input demands are, in most cases, relatively inelastic. Simulation of the model for six different policy scenarios reveal that effects on the Swedish base industry of a EU-level permit-trading system depends on (i) the removal or maintenance of the current CO_2 tax, (ii) the price of permits, and (iii) the future price of electricity. Our analysis shows that changes in electricity price may be more important than the price of permits for some sectors.

Keywords: CO_2-emissions; Factor demand; Tradable permit market

1. Introduction

The objective of this study is to evaluate the potential effects on Swedish manufacturing industry in terms of CO_2 emissions, input demand, output and profits of the newly started CO_2 emission trading scheme (ETS) within the EU. This paper develops an econometric partial equilibrium model for the Swedish industrial sector (with a focus on the energy-intensive industries), which relies on firm-level data from 1990 to 2001. This methodology provides estimates of supply as well as demand elasticities via the parameters of the model. These elasticities are then used in a second step to simulate a system of emission trading under various assumptions. The analysis is relevant for several reasons. For example, the Swedish industry is energy intensive. Thus, the ETS is likely to have considerable effects on output decisions and input substitution. From a general point of view, it is of interest to assess the impacts of the ETS considering a future broadening and tightening of the system.

The background to our study comes from the text of the Kyoto protocol concerning flexible mechanisms to meet greenhouse gas emission targets. According to Article 17, Annex I countries could meet their obligations through the use of emissions trading. Starting on 1 January 2005, the Emission Trading Scheme (ETS) was launched within the European Union. During the first trading period (2005–2007) the ETS applies only to CO_2 emissions from large emitters in the power- and heat-generation industry and other energy-intensive industrial sectors.[1] A threshold based on production capacity, or output, determined which plants in these sectors were included in the scheme. In the

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[1]These included combustion plants, oil refineries, coke ovens, iron and steel plants, and factories making cement, glass, lime, bricks, ceramics, and pulp and paper.

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first trading phase, approximately 11,500 installations in the 25 Member States are covered, accounting for approximately 45% of the EU's total CO_2 emissions (European Commission, 2005). Due to the relatively energy intensive nature of Swedish industry it is of interest, for at least two reasons, to study the effects on the Swedish industry. Firstly, the ETS will imply an explicit price on CO_2, which directly affects the industry in the form of a price increase for fuels that emit CO_2 (primarily fossil fuels). Secondly, and perhaps more important is the indirect effect on the market for electricity. This indirect effect is that the ETS will likely impose additional costs on fossil-fuel-intensive electricity generation in Europe, which in turn may put an upward pressure on the price of electricity. Since the electricity markets have become more integrated this effect may spill over also on the Swedish electricity market in terms of higher prices. This in turn may have significant effects on the Swedish industry. In Section 5, we use our estimated econometric model, in conjunction with several policy scenarios, to simulate these potential impacts.

The use of a partial equilibrium econometric approach is based on the availability of a large time-series/cross-sectional dataset. The panel set includes all firms with more than 5 employees within the industrial sector between 1990 and 2001. An alternative modeling approach for these data might be to employ a computable general equilibrium model (CGE). This approach was used in Hill and Kriström (2002, 2005), and Nilsson and Kriström (2002), where policy scenarios similar to those in this paper were evaluated. The most obvious advantage of the econometric approach, however, is that the estimated parameters of the model are based on actual firm behavior in several time periods, a property that too often is lacking in the CGE approach. CGE analysis will, although mainly based on single-period data and often *ad hoc* parameterization, have the ability to track repercussions throughout the whole economy, not just the sector analyzed. This is by assumption not possible in partial equilibrium econometric models. From our perspective the two modeling approaches have their pros and cons, and serve more as complements to each other.

The paper is structured as follows. We briefly present the theoretical model underlying the empirical analysis in Section 2, and data and the final empirical specification in Section 3. We provide the estimation results in the form of output and demand elasticities in Section 4. In Section 5, we present various simulations given different assumptions about the permit market, current CO_2 tax, and electricity price. Section 6 contains some concluding comments.

2. Theory

In this section, we derive the model that will be used in the empirical analysis. The model is based on standard microeconomic foundations, assuming that each firm (a) maximizes profits, (b) operates in a competitive environment, and (c) has a technology that transforms inputs to a single output (and a byproduct) in an efficient way. Assumption (a) implies, among other things, that given an output decision, each firm will choose a bundle of inputs that minimizes costs. Assumption (b) implies that all input and output prices are exogenous to the firm. Assumption (c) implies that we can describe the technology with a production function.[2]

More specifically we assume that the firms are using an input vector $\mathbf{x} = [x_1, \ldots, x_n]$ to produce a single output q. Denote the corresponding input price vector as $\mathbf{w} = [w_1, \ldots, w_n]$, and the corresponding output price p. Then, given the assumptions above we can write the profit function for a representative firm as

$$\pi = pq^* - \mathbf{w}'\mathbf{x}^* = \pi(\mathbf{w}, p), \tag{1}$$

where q^* and $\mathbf{x}^*$ are the profit maximizing output and input choice.

The profit function in (1) has the usual properties (i.e. increasing in p, non-increasing in $\mathbf{w}$, homogenous of degree 1 in p and $\mathbf{w}$, and convex in p). Then, by applying Hotelling's lemma to Eq. (1) we obtain output supply and input demand as functions of all prices:

$$\nabla_p[\pi(\mathbf{w}, p)] = q(\underset{+}{p}, \underset{-}{\mathbf{w}}), \tag{2}$$

$$-\nabla_{\mathbf{w}}[\pi(\mathbf{w}, p)] = \mathbf{x}(\underset{-}{\mathbf{w}}, \underset{+}{p}). \tag{3}$$

The sign under each argument denotes the expected sign. Economic theory predicts that the own price supply effect is positive, whereas the effect on supply from an increase in any input price is negative. The negative sign under $\mathbf{w}$ in Eq. (3) denotes the own price demand effect, whereas the question mark (?) denotes the cross-price effects that cannot be signed *a priori*. The sign of the cross price effect will depend on the technology (i.e., whether inputs are gross substitutes or gross complements in production). The term *gross* is used to indicate that a price change may lead to two different effects: a substitution effect and a scale (production), effect. The latter is due to a change in the profit maximizing level of production, which may reinforce, or weaken, the pure substitution effect. That is, even if energy and labor are substitutes from a pure technological point of view, the scale effect from an increase in the energy price may lead to a decrease in labor input, i.e., energy and labor may be net substitutes and gross complements at the same time.[3] Which measure to be used, net or gross, is a matter of the objective with the

[2]As a by-product to q we assume that the firm produces a "bad" output, namely CO_2. We make the reasonable assumption that CO_2 is produced in a fixed proportion to the input of fuel. Thus, any reduction of CO_2 emissions can only be accomplished by a reduction in fuel input. Therefore, an increase of the CO_2 taxaffect firm profit through a higher input price (fuel). By assuming a fixed proportion between q and CO_2 we do not have to consider the "multi-output" property explicitly.

[3]It can be shown under what conditions inputs can be net substitutes and gross complements, or vice versa, at the same time. The interested reader is referred to Chambers (1988).