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Carbon intensity in production and the effects of climate policy—Evidence from Swedish industry

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HIGHLIGHTS

- We analyze environmental performance (EP) at the firm level and the effectiveness of environmental policy in Swedish industry 1990–2004.
- Results show that EP has improved in all sectors of manufacturing.
- We also see a decoupling of economic growth and emissions.
- Firms′ EP responds to changes in the CO_2 tax and fossil fuel price, but is more sensitive to the tax.

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ABSTRACT

We analyze carbon intensity performance at firm level and the effectiveness of the Swedish CO_2 tax. Carbon intensity performance is derived from a production technology and measured as changes in the CO_2 emission-output production ratio. As one of the first countries to introduce a CO_2 tax in 1991, Sweden serves as an appropriate "test bench" for analyzing the effectiveness of climate policy in general. Firm level data from Swedish manufacturing spanning over the period 1990–2004 is used for the analysis. Results show that EP has improved in all the sectors and there is an evidence of decoupling of output production growth and CO_2 emissions. Firms′ carbon intensity performance responds both to changes in the CO_2 tax and fossil fuel price, but is more sensitive to the tax.

1. Introduction

The objectives of this paper are to (1) derive and evaluate a measurement of carbon intensity performance in Swedish manufacturing during 1990–2004 and (2) to explore its determinants, especially the Swedish CO_2 tax. The analysis is empirical and we adopt a micro-economic perspective. Concerning carbon intensity performance *per se*, this paper is linked to the discussion of decoupling of output production and emissions, and the Environmental Kuznets Curve (EKC). Both these concepts are connected to breaking the link between growth in emissions and growth in produced output.[1] The unique firm level data available to us, together with the ambitious Swedish climate policy, gives us a unique opportunity to shed light on pertinent policy issues, in this case the effectiveness of a CO_2 tax.[2] To learn from the Swedish case, we believe, can therefore be very relevant for countries that are in the process of shaping their own climate policies.

Two types of decoupling between CO_2 emissions (one type of bad output) and produced output (good output) are discussed in the literature: relative and absolute (Azar et al., 2002). Relative decoupling is when emissions grow at a slower rate than economic growth. Absolute decoupling is when emissions decline while the economy grows. Most decoupling studies are descriptive in its nature in the sense that there are few or no attempts to explain and find the underlying drivers for the path of emissions and economic growth, or the relation between them. Rather they

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[1] The notion of coupling and decoupling between different outputs in production can be traced back to Frisch (1965).

[2] Carbon intensity of production is, we believe, a relevant criterion for analyzing the effectiveness of climate policy. The atmosphere works as a sink of greenhouse gases and especially CO_2. To lower overall greenhouse gas concentrations it is important to lower CO_2. The purpose of the CO_2 tax directed towards manufacturing firms in Sweden is to lower emissions from that sector, and as a consequence also lower concentrations of greenhouse gases in the atmosphere. However, the tax has to be administered so that production and competitiveness is not hampered too much. Therefore, a measure of carbon intensity in production is an adequate criterion for assessing the effectiveness of climate policy.

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focus how changes in emissions can be decomposed into different factors such as changes in output, energy intensity, industry structure, fuel mix, and utility mix (see e.g., Diakoulaki and Mandaraka, 2007). An exception is Enevoldsen et al. (2007) who study sector level energy consumption in energy intensive industries in Scandinavia. Their study differs from most of the decoupling literature in the sense that they analyze the drivers behind the development of energy consumption by estimating a factor demand system.

The EKC literature (see e.g., Grossman and Krueger, 1995; Selden and Song, 1994; Stern, 2004; Dinda, 2004; Galeotti et al., 2006) differs from the decoupling literature in the sense that EKC studies do not focus on decomposition of emissions or energy consumption, but rather the direct connection between economic growth (usually national level GDP) and emissions. As for the decoupling literature many studies of the EKC are comparative macro-level studies based on panel data for countries. There are numerous surveys of the EKC literature (see e.g., Stern et al., 1996; de Bruyn, 2000; Dinda, 2004; Stern, 2004; Bo, 2011). Most of these studies reveal mixed results concerning the relationship between output growth and emissions. See Kriström and Lundgren (2005) for an EKC study on aggregate CO_2 emissions in Sweden 1900–2010.

Although studies at aggregated levels (country or sector level) provide important information on carbon intensity performance in society, it is also important to understand carbon intensity performance and its determinants from a firm level micro-perspective. All emissions originate from individual sources with different carbon intensity performance and prerequisites of improving its performance. Studies that try to understand how these sources respond to specific climate policy measures are rare. Cole et al. (2013) claim to provide the first firm level analysis on carbon intensity performance and its determinants in Japanese manufacturing. However, they do not explore the impact of explicit climate policy measures on firms′ carbon intensity performance, and their performance measure lacks theoretical underpinnings (they simply use the emission-output ratio level). They try to capture the impact of regional lobbying pressure of environmental policy explicitly by approximating this pressure with a number of variables such as regional manufacturing output as a share of total output, population density, the number of officials monitoring pollution control, etc.[3] Key determinants of carbon intensity performance are found to be firm size, capital–labor ratio, and R&D. From the perspective of assessing climate policy the contribution of our study adds to Cole et al. (2013) in several ways: (i) we assess the impact of actual CO_2 taxation on firms′ carbon intensity performance; (ii) performance is measured as emission intensity change, not intensity level; (iii) our assessment concerns 13 individual sectors, not only the overall manufacturing sector; and (iv) our panel data spans a longer period, not only 1 year.

In a recent study of Swedish manufacturing sector level data (1993–2008) Martínez and Silveira (2013) analyze CO_2 intensity in production in relation to policy variables. However, their performance measure is not anchored properly in production theory, and using sector level aggregate data is clearly a disadvantage compared to the level of detail in firm level data. When assessing the impact of climate policy it is logical to investigate how firms′ actually respond to the policy, which we accomplish by applying an emission intensity *change* index. The index we apply is well founded in production theory. A Malmquist-type[4] of index is used to evaluate carbon intensity performance at the firm level separately for all sectors in Swedish manufacturing during 1990–2004. In the index literature, this kind of indicator is usually referred to as "environmental performance" since it can be expanded to include any number of good and bad outputs. Tyteca (1996) reviews indicators of firm level environmental performance using linear programming techniques. Zhou et al. (2008) survey Data Envelopment Analyses (DEA) with focus on energy and environmental studies. The present study assess carbon intensity performance following Färe et al. (2004, 2006, 2010), where a Malmquist-type of index is derived and applied to data.

Having access to data on actual expenses for CO_2 taxation, we are able to model and estimate the impact of one of the most relevant climate policy measures. Also, it is likely that firms in different sectors respond differently to CO_2 taxation, and it is therefore natural to study each sector separately. For instance, do firms in energy intensive sectors respond differently to CO_2 taxation than firms in non-energy intensive sectors? Finally, the stringency of carbon policy and the fossil fuel price may develop differently over time, and studying a longer period of time then brings further insights of these determinants of carbon intensity performance. To our knowledge, no study have provided industry-wide, firm level evidence of carbon intensity performance in relation to policy for a country over such a long time period.

The results show that the Swedish manufacturing industry became 45 percent less carbon intense by reducing emission with 10 percent and increasing production with 35 percent during 1991–2004, and that the CO_2 tax is a significant reason for this development. Hence, the analysis in this paper gives important insights into firms′ carbon intensity performance in Swedish industry, and to learn from the Swedish case, we believe, can therefore be very relevant for countries that are in the process of shaping their climate policy.

The paper is structured as follows: in Section 2 we offer a description of the development of the CO_2 tax in Sweden; Sections 3–5 present the empirical approach, the data, and the results; a discussion and some concluding remarks are given in Section 6.

2. The Swedish CO_2 tax

In connection with the oil crises in the 1970s the reasons for taxation in Sweden were extended to explicitly incorporate the energy perspective (Brännlund, 2009, p. 204). A tax policy that was intended to reduce oil consumption was introduced and was combined with expanding the capacity of nuclear power for electricity production. During the 1980s the arguments for taxation of energy shifted somewhat towards environmental concerns. In 1986, for example, the tax on gasoline was differentiated to distinguish between leaded and unleaded gasoline. This turned out to be very effective since leaded gasoline was phased out in a few years. In the beginning of the 1990s, a major tax reform was implemented in Sweden. The reform covered the entire tax system in Sweden, including energy and environmental taxes. The reform further strengthened the difference between energy taxes and environmental taxes, by incorporating, among other things, the introduction of taxes on sulfur (S) and carbon dioxide (CO_2). In the subsequent energy tax reform in 1993 the energy and the CO_2 tax rates were substantially increased, however, with the exception the manufacturing sector that was exempted from the energy tax, and only taxed at 25 percent of the CO_2 tax.

Fig. 1 displays the historical development of the CO_2-tax rate in Sweden for both the industrial and non-industrial sectors. At first glance Fig. 1 reveals that there is a positive trend in the CO_2 tax rate. The CO_2 tax was introduced in the beginning of 1991 and, as is shown in the figure, the non-industrial tax rate has more than

[3] They lack data on industry specific climate regulation. The effects of regulation are assumed to be captured by firm specific dummies together with other industry specific effects.

[4] See Malmquist (1953) or Färe and Grosskopf (2003).