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The carbon dioxide emissions of firms: A spatial analysis

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ABSTRACT

In order to gain a greater understanding of firms' 'environmental behaviour' this paper explores the factors that influence firms' emissions intensities and provides the first analysis of the determinants of firm level carbon dioxide (CO_2) emissions. Focussing on Japan, the paper also examines whether firms' CO_2 emissions are influenced by the emissions of neighbouring firms and other possible sources of spatial correlation. Results suggest that size, the capital–labour ratio, R&D expenditure, the extent of exports and concern for public profile are the key determinants of CO_2 emissions. Local lobbying pressure, as captured by regional community characteristics, does not appear to play a role, however emissions are found to be spatially correlated. This raises implications for the manner in which the environmental performance of firms is modelled in future.

1. Introduction

While policymakers and business leaders are increasingly aware of the linkages through which industrial production can affect the natural environment, patterns of 'environmental behaviour' continue to differ widely across firms, even when those firms reside within the same industry and country [29,5].[1] If global environmental degradation is to be more effectively controlled, a necessary first step would seem to be to gain a deeper understanding of the causes of such cross-firm variation in emissions and other aspects of environmental behaviour.

A growing body of literature has examined the determinants of firms' environmental management practices [20,29] and has highlighted the roles played by a range of internal factors such as firm size and ownership structure as well as external factors, including environmental regulations, environmental lobbying and globalisation pressures. A weakness of this literature has always been the uncertain link between environmental management and actual measures of environmental performance such as emissions. A smaller body of literature has therefore attempted to directly examine measures of environmental performance, in the form of toxic air releases or local air pollution, and to identify the factors that influence them (see for example Kahn [24], Shadbegian and Gray [32] and Gray and Shadbegian [16]). These studies have also typically highlighted a range of factors both internal and external to the firm or plant, although data limitations have meant that this body of work focuses exclusively on the US, often concentrating on specific states or industries.

A more recent study by Gray and Shadbegian [15] has extended the previous US environmental performance literature by allowing the fact that the determinants of plant-level environmental performance considered in the above studies may

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[1] We use the broad term 'environmental behaviour' to encompass firms' environmental systems and policies, often referred to as environmental management, but also firms' actual environmental performance, often measured by pollution emissions.

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be influenced by spatial factors. Environmental performance could be spatially correlated for a number of reasons. For instance, firms and plants may be subject to location-specific environmental regulation (or enforcement) or environmental lobby groups. Additionally, industry agglomeration may result in concentrations of similar types of firms with similar levels of pollution intensity. If spatially correlated explanatory variables of this type are omitted from an econometric analysis there will be spatial dependence within the error term. The solution to this problem is normally to estimate a spatial error model in which the error term is spatially lagged. Another reason why environmental performance might be spatially correlated is if firms allow 'best practice' in pollution control to be passed between them via demonstration or imitation effects. Furthermore, if firms are subject to 'yardstick competition', and know their environmental performance is judged by consumers or regulators by making comparisons across firms, they may adjust their own environmental performance in response to that of other firms. In these two situations a firm's environmental performance is dependent on the environmental performance of other firms which necessitates the inclusion of a spatially lagged dependent variable in the estimation model.[2] Using a sample of plants based around three US cities, Gray and Shadbegian find evidence of spatial correlations in terms of regulatory compliance but not in terms of local air emissions. They suggest that a reason for the latter result may be the smaller sample of 299 plants for which toxic release data were available and 102 plants for which local emissions data were available (compared to their main sample of 521 plants).

With this background in mind, this paper examines the determinants of firms' carbon dioxide (CO_2) emissions using a unique Japanese firm-level dataset spanning the manufacturing sector. We make the following specific contributions. First, to the best of our knowledge, this is the first study to examine the determinants of firms' CO_2 emissions, despite the fact that climate change has arguably attracted more attention from policymakers in recent years than any other environmental problem. This neglect of CO_2 reflects the lack of data available for this pollutant at firm or plant-level, a limitation now remedied by our Japanese dataset. Second, again to the best of our knowledge, this is the first firm-level study of a measure of air pollution emissions for a country other than the US. Finally, for the first time, we consider the extent to which firms' emissions of CO_2 are spatially correlated.

The remainder of the paper is structured as follows: Section 2 provides background information on CO_2 emissions in Japan; Section 3 discusses the supply of, and demand for, pollution, the equilibrium level of pollution and possible spatial influences on pollution; Section 3 discusses data and outlines our econometric methodology; Section 4 provides our results and Section 5 concludes.

2. Background: carbon dioxide emissions in Japan

Carbon dioxide is a greenhouse gas, believed to contribute to anthropogenic global warming. Although its global warming potential is the lowest of all greenhouse gases when measured on a per unit basis, because far more units of CO_2 are released compared to the other greenhouse gases, its overall warming impact is believed to be the greatest [13]. The main source of CO_2 emissions is the burning of fossil fuels. Until recently it was believed that the adverse impacts of CO_2 emissions arose entirely through its contribution to global warming, with no known local impacts. However, a recent study by Jacobson [23] argues that the carbon dioxide domes which form over urban areas have the effect of increasing concentrations of local ozone and particulate matter, both of which have adverse effects on human health.

In 2008, Japan was the 5th largest emitter of CO_2 emissions, behind China, the USA, India and Russia and was responsible for 4.01% of global emissions.[3] As Fig. 1 shows, Japanese per capita CO_2 emissions appear to have stabilised in recent years although they have yet to decline.[4] Fig. 1 also provides CO_2 intensity, defined as kilograms of CO_2 per US $ of GDP (in 2000 dollars), and illustrates that this has declined steadily from a peak in 1973, indicating that the Japanese economy has become more energy efficient.

The chief contributors to Japanese CO_2 emissions are the electricity producers, followed by the Iron and Steel, Chemicals, Petroleum, Paper and Cement industries.[5] Since the share of GDP provided by many of these industries has contracted in recent years, these compositional changes will explain, in part, the falling pollution intensity in Fig. 1, although environmental regulations, technological advances and greater energy efficiency more generally are also likely to have contributed.[6] We now more formally consider the factors that influence the supply of, and demand for, pollution emissions.

3. Pollution supply and demand

Following Pargal and Wheeler [30] and Cole et al. [8], we model pollution in terms of the supply of, and demand for, environmental services. Such services form an input into a firm's production function, with the equilibrium level of environmental services reflecting the interaction of a firm's demand for them together with the quantity that society is prepared to supply.

[2] Although not explicitly considered by Gray and Shadbegian [15], it is also possible that the characteristics of other firms may affect a firm's environmental performance. This requires the inclusion of spatially lagged explanatory variables, often in the context of the Spatial Durbin model.

[3] United Nations Statistics Division, Millennium Development Goals indicators (http://mdgs.un.org/unsd/mdg/Default.aspx).

[4] Since population growth in Japan is close to zero total CO_2 emissions follow a very similar path to per capita emissions.

[5] Japanese Business Federation.

[6] Japanese regulations aimed at tackling CO_2 emissions are discussed in Section 3.2.