Does the 'California effect' operate across borders? Trading- and investing-up in automobile emission standards

Revised Version, October 2010

Forthcoming in *Journal of European Public Policy*

Richard Perkins, r.m.perkins@lse.ac.uk

Eric Neumayer, e.neumayer@lse.ac.uk

Address, both: Department of Geography and Environment and Grantham Institute on Climate Change and the Environment, London School of Economics and Political Science, Houghton Street, London WC2A 2AE, UK

Fax: +44 (0)20 7955 7412

Tel: +44 (020) 7955 7605

Acknowledgements

The authors would like to acknowledge the generous support of the United Kingdom's Economic and Social Research Council (ESRC), award #RES-000-22-2753. We thank three anonymous referees, M.J. Peterson, Rob Franzese, as well as panel participants at the 2010 Royal Geographical Society and American Political Science Association meetings for their helpful and constructive comments.

Does the 'California effect' operate across borders? Trading- and investing-up in automobile emission standards

Abstract

The 'California effect' hypothesis posits that economic integration may lead to the ratcheting upwards of regulatory standards towards levels found in higher-regulating jurisdictions. Although a number of previous large sample quantitative studies have investigated such convergence dynamics for public environmental policies, their results have been based exclusively on geographically and sectorally aggregated data. Our contribution advances on these studies. We provide the first large-N, geographically disaggregated evidence consistent with a trading-up effect: exports of automobiles and related components from developing countries to countries with (more stringent) auto emission standards are found to be associated with (more stringent) domestic emission standards. Investing-up dynamics are also apparent, with aggregate inward FDI into host developing economies' automotive sector increasing the likelihood of more stringent emission standards domestically.

Automobiles, California effect, convergence, investing-up, standards, trading-up

Introduction

Recent work concerned with the regulatory implications of globalisation has acknowledged the possibility that economic integration might be instrumental in raising the stringency of domestic environmental standards. Highly influential in this regard has been the work of Vogel (1995) who has invoked a 'California effect' to describe the tendency of environmental product standards to ratchet upwards towards levels found in major, high-regulating countries. Vogel placed particular emphasis on trade as a vehicle for upwards harmonisation, while developing on his idea of 'trading-up', scholars have hypothesised the existence of a similar 'investing-up' effect arising from foreign direct investment (FDI) (Garcia-Johnson 2000; Prakash and Potoski 2007).

Yet, while qualitative case-studies have offered evidence for a California effect in public environmental policy (e.g. Garcia-Johnson 2000; Tewari and Pillai 2005), findings from more generalizable analyses using large-sample, quantitative techniques have been less than convincing. One reason for this state of affairs is that previous cross-national studies which have analysed public environmental policy adoption, stringency or convergence have relied exclusively on geographically aggregated measures of economic integration such as trade openness (Arts et al. 2008; Damania *et al.* 2003; Liefferink et al. 2009; Lovely and Popp 2008; Sommerer et al. 2008). This is problematic, in that the California effect thesis posits that it is economic linkages with higher-regulating markets in particular which stimulate ratcheting-up, a prediction that can only be tested using geographically disaggregated data and spatial econometric models. Another reason why existing previous quantitative works are less than convincing is that they have used sectorally aggregated data which capture trade and investment in all economic sectors (Cole *et al.* 2006; Lovely and Popp 2008). These include sectors which have little or nothing to do with particular environmental policies under investigation with the corollary that past studies have run the risk of generating spurious findings. Finally, while the influence of trade has received attention from a number of scholars, the role of FDI on ratcheting-up in public environmental policy remains largely un-researched in the large-N, quantitative literature.

Our contribution seeks to address some of these shortcomings. Advancing on previous work, we use geographically disaggregated trade data to construct a so-called spatial lag variable, which allows us to examine whether exporting to countries with more stringent environmental standards "spills-over" domestically into more stringent standards in developing countries. We also expand on most past studies by additionally analysing the influence of FDI. Another advance is that we restrict our analysis of trade and investment to specific sectors most likely to affect the stringency of environmental standards.

Empirically, we make use of a new global dataset of automobile emission standards to test whether the California effect operates – via exports and inward FDI – across borders for a large sample of developing countries. Automobile emission standards make a good test case because not only have they been adopted by a large number of countries (Knill et al. 2008), but, conceptually, they should be especially susceptible to trading- and investing-up. As explained below, this is because emission standards constitute environmental product standards, the automotive sector is characterised by significant cross-border trade and investment, and manufacturers face strong economic incentives to harmonise product specifications across different markets (Scharpf 1997; Vogel 2000). Automobile emission standards also have analytic advantages in that it is possible to acquire sectoral trade and investment data which pertains directly to cars (i.e. automobiles and related components).

Unique to the literature, our contribution provides the first large-N, geographically disaggregated empirical support for a trading-up effect. We thus find robust evidence that exports of automobiles and related components from developing countries to countries with (more stringent) auto emission standards is associated with (more stringent) domestic emission standards. Investing-up dynamics are also apparent, with aggregate inward FDI into host developing economies' automotive sector increasing the likelihood of more stringent emission standards domestically.

Ratcheting-up of environmental standards through global economic integration

Recent discussions about the California effect are part of a longer-standing debate about the extent to which globalisation contributes to growing similarity between countries over time, that is, cross-national convergence (Bennett 2001; Holzinger and Knill 2005; Prakash and Kollman 2003; Young 1969). Within the context of environmental policy, earlier work was dominated by ideas of downwards convergence, and specifically the prediction that inter-state competition would stimulate national governments to lower domestic environmental standards (the 'race-to-the-bottom' thesis) or else make them reluctant to raise them (the 'regulatory chill' thesis) (Rodrik 1997; Tienhaara 2006; Zarsky 2002). Underlying such claims was the oft-made assumption that environmental standards add to production costs, providing an economic incentive for regulatory targets to oppose tightening (Whalley and Whitehead 1994).

Revisionist accounts have questioned this logic, pointing to the possibility of upwards convergence, especially in the case of environmental product standards (Jänicke and Jacob 2004; Rugman and Verbeke 1998; Vogel 1995). Specifically, it is suggested that under certain circumstances the benefits for corporate actors from raising environmental standards to levels found in higher-regulating jurisdictions may actually outweigh the costs, creating incentives for these parties to lobby for upwards harmonisation.[1] These include situations where (a) major export markets impose more stringent environmental product standards and (b) major direct investments are received from higher-regulating countries. We review these cases in turn.

Trading-up via exports

The idea that exporting to higher-regulating economies raises domestic regulatory stringency has been popularised in the concept of trading-up (Neumayer and Perkins 2004; Prakash and Potoski 2006; Vogel 1997; Greenhill *et al.* 2009). Trading-up is said to arise from the presence of 'market-access regulations' (Murphy 2004), constituting environmental product standards which can be used by national governments to ban non-compliant imports under World Trade Organisation rules. Market access regulations provide a direct economic incentive for firms in country *i* wishing to export to higher-regulating markets *k* to re-engineer their products to conform to standards found in the latter in the sense that it allows them to maintain or expand foreign sales. Moreover, as export-oriented firms develop the capabilities to comply with standards in their major export markets, so they may lobby governments to adopt similar environmental standards domestically (Vogel 1995). This is because: (a) producing a single product for both home and export markets allows firms to benefit from greater economies of scale; and (b) tightening domestic environmental standards may grant exporters a commercial advantage over their home market competitors lacking requisite compliance technologies by raising the latter's relative costs (Bach and Newman 2007; Heyes 2009; Körber 1998; Lazer 2001).

However, the literature suggests that trading-up is not automatic, but is most likely to take place when countries export to large, high-regulating markets (Beise and Rennings 2005;

Drezner 2005; Falkner 2006; Vogel 1995). At a fundamental level, domestic firms should be more inclined to re-engineer their products for larger markets, in the sense that the costs of doing so are more likely to be outweighed by export revenues (Drezner 2005; Princen 2004). Further, because of the importance of achieving cost competitiveness in markets which account for a higher share of overall sales, firms will have greater incentives to produce a similar product for the domestic market so as to fully exploit economies of scale. Indeed, the size of the producer constituency with a direct financial stake in upwards harmonization should be larger where domestic firms are more dependent on big, high-regulating markets, leading them to exert more pressure on governments to introduce similar standards domestically. For their part, governments might be more willing to accede to calls for upwards harmonisation to levels found in major markets, aware that the adjustment costs of complying with more stringent standards domestically may be offset by payoffs such as increased export competitiveness (Genschel and Plumper 1997; Vogel 2000).

What constitutes a "large" market is open to interpretation. Vogel (1995) himself refers to individual economies which are relatively big and wealthy, but large markets might equally be created by multiple smaller countries with similarly stringent environmental regulations.

Investing-up via inward FDI

Another form of economic integration widely implicated in regulatory harmonisation is created by FDI. Bennett (1991) describes the mechanism by which foreign investors create pressures in host economies for cross-market regulatory standardisation as 'convergence through penetration'. Within the context of upwards convergence in environmental policy, however, scholars have used the term ‘investing-up’ (Perkins and Neumayer 2010; Prakash and Potoski 2007).

A common starting point for accounts of investing-up is the observation that many of the world’s TNCs originate, or else variously operate, in high-regulating developed economies, and therefore have developed the capabilities to comply with more stringent environmental standards (UNCTAD 2007). Further, they are known to transfer their environmentally-superior process and product technologies to foreign affiliates and subsidiaries in lower-regulating countries (OECD 1997). This is because it may be costly to substantially re-engineer technologies to suit different environmental regulatory requirements and higher-profile TNCs may face criticism from civil society if they are seen to deploy environmentally inferior technologies in host countries (Vogel 2000). In turn, the transfer of standardised, beyond-compliance technologies creates incentives for TNCs to lobby for the upwards harmonisation of environmental standards in order to ensure regulatory consistency across the different markets in which they operate (Birdsall and Wheeler 1993; Garcia-Johnson 2000). These incentives derive from the fact that: (a) in the absence of higher standards, TNCs’ beyond-compliance product technology which they operate in other markets may be price uncompetitive with the offerings of compliance-only local competitors; and (b) raising domestic environmental standards potentially places indigenous firms at a competitive disadvantage in that they lack experience of requisite compliance technologies and may therefore find it more costly to comply (Heyes 2009; Rugman and Verbeke 1998).

As with exports, however, ratcheting-up is likely to be positively influenced by scale effects. A larger volume of FDI implies a larger constituency of TNCs with more political resources to lobby for regulatory tightening and to thwart domestic industrial opposition to more stringent standards (Vogel 1995). To the extent that higher levels of FDI might well reduce the economy-wide adjustment costs of upwards harmonisation, and demonstrate the feasibility of raising standards domestically, it may also shift the preferences of domestic actors (e.g. governments, consumer groups, etc.) towards regulatory tightening.

Previous studies and their shortcomings

Much of the recent evidence for a cross-border California effect – understood here as the ratcheting-up of domestic standards towards levels found in a country's major high-regulating economic partners via trading-up and investing-up effects – has come from research which has analysed the diffusion of voluntary codes-of-conduct. [2] A large number of studies have shown that exports to, and inward investment from, countries which have a higher number of adopters of a particular code, e.g. ISO14001, increases the domestic adoption of the same code (Albuquerque et al. 2007; Corbett and Kirsch 2001; Neumayer and Perkins 2004; Perkins and Neumayer 2004, 2010; Prakash and Potoski 2007). Although consistent with trading- and investing-up of private environmental standards, this research says nothing about whether exports or inward FDI have a ratcheting-up effect on public standards. The distinction is an important one in light of a growing empirical literature which demonstrates that private environmental codes typically have comparatively little, or even no, "positive" effect on the environmental performance of participants or domestic environmental quality (Koehler 2007). Indeed, if the existence of a California effect is to be used to support wider arguments about the substantive environmental benefits of economic integration, it would seem necessary to focus greater attention on public environmental standards.

Current understanding in this area mainly derives from qualitative case-study research. Apt in the present context are several studies which have documented how Germany successfully exerted pressure on the European Commission to adopt more stringent auto emission standards in the 1980s in the European Community, the predecessor to the

European Union (EU).[3] This demand for regulatory tightening was fuelled by growing public and political concern in Germany about the effects of 'acid rain' (Hagner 2000). Yet, government support for more stringent EU-wide standards was considerably strengthened by the fact that German vehicle manufacturers were major exporters to the higher-regulating US market, and therefore already producing vehicles capable of complying with more stringent standards (Boehmer-Christiansen and Weidner 1995; Vogel 1997). Raising regulatory standards across the EU closer to US levels gave German firms a competitive advantage over some of their EU rivals – at least in the short-term (Hagner 2000). A similar story of market integration leading countries to emulate more stringent automobile emission standards in their major trade and investment partners has been documented elsewhere, e.g. Canada (Hoberg 1991). Several case-studies also provide evidence confirming aspects of the trading-up hypothesis specifically in the case of developing countries. For example, Tewari and Pillai (2005) describe how environmental standards imposed by Germany, the leading buyer of leather goods from India, led the Indian government to introduce a law banning the import and production of chemicals specified in Germany legislation. More generally, the case study literature concerned with the hypothesised race-to-the-bottom has documented how trade and investment openness have created pressures in some rapidly industrialising countries for regulatory tightening towards levels found in developed economies, both by market and civil actors (Birdsall and Wheeler 1993; Jenkins 2000).

Although suggestive, these case-studies hardly provide conclusive evidence of a generalised cross-border California effect. Most importantly, they cover only a small number of countries, and it remains unclear as to whether instances of ratcheting-up via exports are the exception rather than the norm. The existing qualitative literature also says comparatively little about the role of inward FDI as a driver for public environmental regulatory tightening.

A number of large-N, quantitative studies have been undertaken which provide more generalisable insights into the relationship between economic integration and environmental policy. For a sample of 48 developed and developing countries, Damania et al. (2003) find that trade openness is positively correlated with the stringency of standards governing lead concentrations in gasoline, a relationship mediated by corruption levels. Likewise, Lovely and Popp (2008) find that developing countries more open to trade tend to adopt public SO_2 and NO_x process standards earlier. Other studies fail to lend clear support to the idea that trade promotes regulatory tightening. For a sample of 21 European and 3 non-European countries, Sommerer et al. (2008) and Liefferink et al. (2009) find only ambiguous evidence that bilateral trade openness contributes to environmental policy convergence, and that any effect of trade is subordinate to the influence of institutional harmonization. For the same group of countries, neither Arts et al. (2008) nor Knill and Tosun (2009) establish a positive correlation between trade and the adoption or stringency of various environmental policies. Compared to trade, very little quantitative work has focused on FDI. Following a similar approach to Damania et al. (2003), Cole et al. (2006) show that inward FDI into 33 developed and developing countries is positively correlated with the stringency of domestic lead standards, with the "positive" effects of inward investment declining with increased corruption.

In sum, the quantitative literature provides mixed evidence regarding the influence of trade, while the role of FDI has received very little attention. Moreover, previous studies suffer from a number of important shorthcomings, which restricts their usefulness in empirically scrutinising Vogel's California effect thesis. One is that the explanatory variables used to capture economic ties fail to distinguish between linkages to higher- or lower-regulating countries. To be fair, this is less of a problem in the case of FDI to the extent that a large share of direct investment originates in developed economies, where standards are presumably more stringent (Busch and Jorgens 2005; Dasgupta *et al.* 2001). Yet for exports the picture is clouded by the fact that developing countries not only trade with developed economies, but with other developing countries, where environmental standards are likely to lag far behind the regulatory frontier (Vogel 2000). Moreover, although conceptual accounts of ratcheting-up emphasise exports, past studies have tended to focus on all trade (i.e. aggregated imports and exports), rather than restricting itself to sectors most likely to affect the supply and demand for environmental regulations governing negative externalities relevant to the dependent variable under investigation. Hence, it seems implausible that FDI in the retail sector should influence environmental standards governing automobile emissions, but entirely plausible that FDI in the automotive sector should impact such regulations.

Our contribution seeks to overcome these shortcomings by making use of a newly-constructed dataset which records the domestic stringency of public automobile emission standards for a large sample of countries. We restrict our analysis to trade and investment in the automotive sector, i.e. to the sector most likely to affect the stringency of domestic vehicular emission standards. For trade, we can construct what is known as a spatial lag variable, allowing us to examine the extent to which exporting more automobiles and automobile components to markets with more stringent emissions standards is associated with more stringent domestic auto standards. For FDI, we cannot do the same due to lack of data that is both bilaterally and sectorally disaggregated, but we still improve on existing work by using sectorally disaggregated data.

Ratcheting-up of automobile emission standards

A brief history of standards

National public automobile emissions standards – governing maximum permissible levels of tailpipe emissions for pollutants from new automobiles[4] – were first introduced in the US, Japan and various European[5] countries in the 1960s and 1970s (Hagner 2000). Our focus in the present article is on a more stringent set of standards, beginning with regulations equivalent to Tier 0 and Euro I, which came into force for new vehicles in the US and EU[6] markets in 1987 and 1992 respectively. Compared to earlier equivalents, these standards were far more technologically demanding, requiring sometimes extensive engine modifications and re-engineering, together with the addition of sophisticated three-way catalytic converters for gasoline cars.

The US and EU have subsequently tightened their standards in a series of incremental steps, requiring yet further technological upgrades, e.g. replacement of carburettor-based gasoline engines with ones featuring multi-point fuel injection (Haščič *et al.* 2009). Hence, US Tier 0 standards were followed by Tier 1 in 1994, NLEV (National Low Emissions Vehicle) standards in 2001, and Tier 2 in 2004. [7] In the EU, Euro 2 was first implemented in 1996, Euro 3 in 2000, Euro 4 in 2005 and, most recently, the Euro 5 standard in 2009.

Importantly, standards equivalent to Tier 0/Euro I and beyond have been "copied" by a range of countries, including a growing number of developing ones (Knill et al. 2008; Timilsina and Dulal 2009). Several economies (e.g. Chile) have mainly based their domestic standards on US ones. Yet the vast majority of developing economies have emulated EU standards (e.g. China, South Africa). Indeed, the EU's Euro regulations have increasingly become the *de facto* standard for countries wishing to mandate significant reductions in vehicular pollution, at least outside North America and Japan. Inevitably, developing countries have mostly lagged developed ones in the respective date that they have implemented particular standards, although evidence suggests that this gap is narrowing over time indicative of policy convergence.

At face value, the presence of a growing number of developing countries adopting increasingly stringent emission standards and, moreover, standards similar to those adopted in the EU and the US strongly hints at the existence of spatially dependent regulatory behaviour (Young 1969). That is, it suggests that the decision to adopt particular emission standards in lagging developing countries has not been taken independently, but has been influenced by regulatory choices in higher-regulating developed countries as well as possibly higher-regulating developing ones (Busch and Jorgens 2005). The question addressed in the present article is whether this apparent spatial dependence is, as predicted by market integration accounts of the California effect, driven by export ties and inward investment into the automobile sector.

Trading- and investing-up?

Automobiles are a volume business. In order to be cost competitive, manufacturers must achieve considerable scale economies, implying large production runs of similar components, systems and models (Orsato and Wells 2007). Another salient feature of the automobile industry is that it is increasingly dominated by large TNCs, who make significant direct investments outside their home country, and organise production on a regional or, less often, global basis (Dicken 2007). As an increasingly transnational assembly business, the multiple components, sub-systems and systems that go into making a finished automobile are often produced in a number of different countries, before being brought together in final assembly.

The automobile industry is also characterised by large volumes of trade, not only of components between and within suppliers and manufacturers in different countries, but also of finished vehicles.

An important corollary of these characteristics – at least for manufacturers operating in multiple markets – is that the existence of similar emission standards in different countries may be economically advantageous. Cross-market regulatory harmonisation allows vehicle manufacturers to achieve greater economies of scale, in the sense that larger volumes of the same "compliance" technologies can be produced for cars sold in multiple markets. These technologies include similar base-engines, incorporating standardised emissions control sub-systems (e.g. electronically-controlled multi-point fuel injection), as well as similar after-treatment technologies (i.e. catalytic converters). Thus, rather than having to design, manufacture and configure different components, systems and models for different countries, car producers can deploy similar ones for markets with equivalent emission standards.

When set in the context of earlier arguments about trading-up, these economic considerations suggest that vehicle manufacturers and suppliers based in lower-regulating economies who export a large share of their output to higher-regulating ones may favour raising domestic standards. Manufacturing the same components, systems and/or entire vehicles with higher environmental performance for both home and foreign markets should help to reduce their unit costs and, importantly, contribute to improved export competitiveness (Hagner 2000; Jänicke and Jacob 2004). Yet there are potential constraints on firms based in low-regulating markets producing technology for domestic sale which exceeds local regulatory requirements. One is that advanced base-engine and after-treatment technologies invariably require higher quality fuels in order to function effectively and reliably. Owing to the costs involved in upgrading refining capacity, domestic fuel quality improvements are mostly driven by government regulations, which themselves typically accompany the adoption of more stringent vehicular emission standards (Timilsina and Dulal 2009).

Another reason why voluntarily going beyond-compliance is not always an option is that vehicles engineered to comply with significantly more stringent emission standards are, all other things equal, invariably more costly to produce (Peake 1997; KPMG 2008). A Euro 3 compliant vehicle is more expensive to manufacture than, say, a vehicle which is Euro 1 compliant because of the more sophisticated base-engine and after-treatment components required. Automotive firms marketing technology which is significantly beyond compliance may therefore struggle to compete against other companies who have advantages in producing compliance-only equivalents. Hence, export-oriented firms wishing to maximise scale economies for technology engineered to comply with higher standards have a strong incentive to level the playing field domestically, pressurising national governments to set the regulatory bar closer to the level found in their major export markets. Indeed, doing so may provide export-oriented firms with a commercial advantage over their domestic competitors who predominantly make vehicles and components with lesser environmental performance for the local market, with the latter likely finding it more costly to engineer emissions compliant technology (Perkins 2007).

We would expect these pressures to harmonise to be greater in countries which export more of their automobiles and automobile components to high-regulating countries (Beise and Rennings 2005). A higher volume of exports to more stringently-regulated foreign markets increases the importance for firms to achieve cost competitiveness in these markets by maximising economies of scale for vehicles and components engineered to comply with more stringent standards. This is likely to increase the incentives to produce similarly specified designs for the domestic market, as opposed to producing smaller batches of environmentally-superior designs for foreign markets, and concentrating on maximising scale economies for vehicles, components or systems engineered to comply with lower standards.

It is equally possible that exports could contribute to ratcheting-up in ways less commonly discussed in the literature on trading-up. Domestic governments might be inclined to look towards their major export partners, taking cues from them as regards appropriate emission standards, and emulating their regulatory choices (Busch and Jorgens 2005; Jänicke and Jacob 2004). Going further, governments may embrace regulatory tightening as part of a strategic industrial policy, raising domestic emission standards in order to increase the competitiveness of domestic firms in higher-regulating export markets. The very fact that beyond-compliance vehicles and associated components are already being manufactured domestically may additionally catalyse demands from environmental NGOs (and other groups with similar interests) for tougher standards locally. The existence of domestic environmental technological capabilities may similarly encourage domestic regulators to tighten standards.

We therefore expect:

> *Countries are more likely to have more stringent domestic vehicular emission standards where they export more automobiles and automobile components to countries which themselves have more stringent vehicular standards*

A similar ratcheting-up effect might come from inward FDI. TNCs face incentives – arising from economies of scale and avoided duplication costs – to deploy similar technologies across multiple markets. In reality, TNCs do not always produce homogenous "global" models, fitted with identical technology, for all countries where they operate. Rather, responding to variations in consumer demand (e.g. for smaller cars), transnational vehicle manufacturers often produce vehicles configured for particular sets of markets such as those in the same macro-region or at comparatively similar levels of income.

Either way, a significant amount of designs, components and systems are shared across different markets. An important consequence of this strategy of cross-market "commonalization" is that vehicles will characteristically be engineered so that they are capable of complying with the most stringent emissions standard served by the model in question. Hence, if a model is designed for a region where a number of markets require Euro 3, the base engine chosen by the manufacturer is likely to be one capable of producing engine-out emissions within these respective limits. Transferred to another country in the region where only Euro 1 is required, this engine may deliver beyond compliance performance.[8] In the case of vehicles produced for countries where standards are non-existent, or else very weak, TNCs such as Ford are known to engineer their vehicles to comply with minimum internal voluntary standards of performance. In fact, even where environmental standards do not require it, TNCs may wish to transfer advanced engine designs to host economies with weak standards because of their superior performance (e.g. in terms of fuel economy, acceleration, etc.). As recognised in theories of multinational production (Dicken 2007), transnationals' ownership of technological resources may provide them with a competitive advantage vis-à-vis local rivals, and deploying their advanced technology can be an important part of TNCs' overall competitive strategy in host markets.

As with exports, TNCs face constraints in deploying standardised, beyond-compliance technologies, including fuel quality and the higher cost of environmentally-superior vehicles. In fact, because of the price-sensitivity of consumers in developing countries, foreign TNCs have to be especially attentive to production costs (Bauner and Laestadius 2003). TNCs wishing to deploy more expensive vehicle technology designed for higher-regulating markets should therefore have strong interests in persuading domestic regulators to raise emission standards (c.f. Birdsall and Wheeler 1993). Higher emission standards are likely to be especially advantageous for TNCs because they help to remove one of the key competitive advantages enjoyed by indigenous manufacturers, that is, their ability to produce low cost, albeit polluting, vehicles using vintage technology (Perkins 2007).

The local presence of TNCs with internal capabilities to comply with more stringent emissions standards may also cause ratcheting-up by convincing governments about the feasibility of adopting higher standards. That is, governments are less likely to be concerned about technical barriers to upgrading, aware that foreign TNCs have ready access to "off-the-shelf" compliance technologies via internal and external networks. More generally, FDI in the sector could also help to lower the costs of regulatory tightening, because inward investment may come from suppliers or engineering consultants who can assist manufacturers meet new standards. Higher levels of FDI may additionally enhance the opportunities available to domestic NGOs to lobby for regulatory tightening, e.g. arguing that there are no technical barriers to achieving higher environmental performance.

We therefore predict:

Countries which receive more inward FDI in the automotive sector are more likely to have more stringent domestic emission standards

This should not be taken to imply that FDI will necessarily give rise to global convergence in emission standards over time. The fact that TNCs produce vehicles for particular sets of markets which share similar characteristics suggests that ratcheting-up is likely to take place towards levels found in higher-regulating countries within these groupings. It does not mean that developing countries will inevitably catch-up with developed economies or that ratcheting-up is inconsistent with ongoing regulatory diversity.

Research Design

Dependent variable: regulatory stringency of automobile emissions

We present results for both a cross-sectional sample, in which the dependent variable is the value of regulatory stringency of petrol vehicles for the year 2008, and a longitudinal panel sample covering the period 1993 to 2008, in which we include country fixed effects in the estimations. The reason for reporting cross-sectional results, in addition to the panel results, is that our sectoral FDI data have many gaps and little over-time variation. Country fixed effects estimation is not well-suited for the latter. However, the panel model has the advantage that the country fixed effects control for unobserved spatial heterogeneity, while year fixed effects control for common shocks.[9] It is thus much more stringently specified. The dataset of regulatory stringency was constructed using a number of different sources, including CAI-Asia (2009), CONCAWE (2006a, b), Continental (1999), Delphi (2009), Umicore Automotive Catalysts (2009) and Walsh (1999). Where there were suspected gaps in coverage, we undertook additional internet searches to investigate further the status of domestic emission standards.

The stringency of emission standards for the developing-country sample was graded on a 0-4 scale. The reference point for our classification is EU standards (Table 1), for no other reason than the majority of developing countries have used the EU's Euro standards as the basis of their domestic emission regulations. Countries were coded 0 if they had no national emissions standards in place for new vehicles or if standards were less stringent than the equivalent of Euro 1. Countries where Euro 1 was legally enforceable were coded 1, and so on, with 4 for countries having implemented the equivalent of the Euro 4 standard.[10] As of

2008, no developing countries in the sample had standards more stringent than Euro 4. For the construction of our export spatial lag variable, which additionally captures levels of regulatory stringency in developed-country export markets (see below), Euro 5 or equivalent standards (e.g. US Tier 2) were coded as 5.

Many expert/official sources make explicit reference to specific Euro standards, or else their ECE equivalent, making it comparatively straightforward to classify countries which have drawn from the EU. Yet coding countries which have not used the Euro standards as the basis of their domestic emissions regulations proved to be more complicated. These countries include the US and Japan, which have innovated their own standards, together with other countries which have made use of these (e.g. Canada and Taiwan). Making comparisons between EU and non-EU emission standards is difficult because: (a) vehicles are tested over different driving cycles; (b) their relative stringency varies across individual pollutants[11]; and (c) emission limit values are sometimes measured in different units. Fortunately, certain countries specify that companies can adopt Euro standards or US standards, e.g. either Euro 5 or Tier 2, making it possible to draw equivalence. A number of professional sources also provide guidance on the equivalence of different countries' tailpipe emission standards (e.g. Peake 1997). With the help of this information, we converted the comparatively few instances of non-Euro standards to Euro equivalent levels of stringency.

Main explanatory variables

We constructed two main explanatory variables. The first is a spatial lag variable which allows us to examine whether more stringent tailpipe emission standards in a country's major automobile-related export markets spill-over domestically into more stringent domestic emission standards. Formally, a spatial lag variable comprises the dependent variable in other countries *k* weighted by a connectivity or weighting matrix capturing the degree of linkage between country *i* and these other country markets *k*. In the present context, the connectivity matrix is constructed using bilateral data from UN (2009), which measures the value of automobiles and automobile components[12] exports from the focal country *i* to countries *k*. Consistent with accounts of export-driven ratcheting-up, our primary interest is on the identity of markets to which a particular country exports more in absolute terms, rather than to whom they export relatively more. We therefore do not row-standardize the weighting matrix (Neumayer and Plümper 2010). Our results are robust to using instead a row-standardized spatial lag variable and, to account for absolute differences across countries, multiplying it by the share of vehicle exports a country accounts for relative to world exports.

A second explanatory variable seeks to capture the influence of inward FDI. A lack of sectorally-disaggregated, bilateral data with widespread geographic coverage means that we cannot construct a spatial lag variable similar to the one that used auto exports as the weighting variable. Instead, we rely on monadic data measuring the value of inward FDI stocks in automobiles and related components from all other economies *k* to the focal country *i*, with data taken from UNCTAD (2009). Although not ideal, in the sense that these data do not capture information about levels of regulatory stringency in investor countries, the vast majority of automotive FDI originates from developed economies with stringent regulations (Dicken 2007; UNCTAD 2007). In any case, our sectorally-refined approach is a marked improvement over many previous studies, which have investigated the links between FDI and the cross-national diffusion of environmentally-superior policy and technological innovations within particular sectors (e.g. power) using data which includes all economic sectors (Cole et al. 2006; Lovely and Popp 2008; Perkins and Neumayer 2005).

Control variables

We also specify a number of control variables. One is GDP per capita (p.c.) which seeks to account for income-dependent variations in the demand for more stringent environmental regulation and the ability to supply this demand. Hence, citizens in wealthier countries should be more likely to demand higher environmental quality, generating political impetus for standards which reduce automobile pollution (Liefferink et al. 2009; Paterson 2007; Wheeler 2001). On the supply-side, political and bureaucratic actors in wealthier countries should have greater capacity to resource the implementation and enforcement of automobile emission standards, and citizens should be better-placed to afford the higher relative costs of emissions-reducing technologies (Timilsina and Dulal 2009). These predictions about income are supported by the empirical record: large-N evidence indicates that poorer countries have lagged in the introduction of more stringent public environmental regulations (Dasgupta et al. 2001; Hilton 2006; Lovely and Popp 2008). Data on GDP p.c. are taken from World Bank (2009).

Another control variable is the number of existing motor vehicles on a country's roads which we use as a proxy for domestic market size. From a conceptual perspective, the impact of market size is ambiguous, potentially exerting a positive *or* negative influence on the strengthening of automobile emissions standards. Regarding the former, a larger internal market is more likely to support the existence of a larger, more diversified domestic manufacturing base, and therefore greater local technological capabilities to upgrade the emissions performance of vehicles (Lall 1992). Likewise, a higher number of vehicles could well be associated with greater administrative resources and expertise in the automotive sector, increasing the feasibility of implementing, monitoring and enforcing emission standards.

Conversely, a larger market could well act as an impediment to regulatory tightening, at least indirectly. Hence, local economies of scale may make it commercially viable to produce country-specific base-engine designs for the domestic market, reducing the incentive to share emissions-reducing vehicle technology with models sold in higher-regulating economies (Lazer 2001). A larger market is also more likely to support the existence of indigenous vehicle manufacturers who, lacking experience of complying with more stringent standards, lobby against regulatory tightening. Data on the number of passenger cars were obtained from IRF (2009).

We also control for urban share which we expect to have a positive influence on the stringency of domestic emission standards. Our reasoning is that a greater proportion of the population living in major urban areas is likely to increase aggregate demand for regulatory interventions to address local environmental degradation. Automobiles are a major source of urban air pollution and regulating emissions from new vehicles provides a comparatively easily-enforceable way to address this externality (Hao et al. 2006). Our data for urban share are taken from World Bank (2009).

Finally, we control for the possibility that economies which are generally more open to international trade and investment may exhibit a higher propensity to implement vehicular emission standards. This might be the case if economic integration accelerates cross-country learning, expanding knowledge of more ambitious environmental standards in other jurisdictions, and stimulating demand for similar environmental regulatory protections domestically. Higher levels of cross-border trade and investment would often infer greater technological dynamism – e.g. manufacturing sector FDI is often attracted by host country technological capabilities – and therefore a greater capacity to upgrade domestic vehicles to comply with more stringent emission standards. Overall trade and investment openness might also render governments more concerned about their economies' external image, increasing their willingness to adopt environmental standards, which signal that a country is more modern, progressive and an attractive location for investment (Busch and Jorgens 2005; Perkins 2007). Controlling for general trade and FDI openness is important to minimise the risk that our sector-specific trade and investment variables do not spuriously pick-up effects that are driven by general openness instead. We measure general trade and investment openness as the share of a country's GDP constituted by international trade and foreign direct investment stocks, respectively, using data from World Bank (2009) and UNCTAD (2009).

Estimation model and sample

The dependent variable is an ordinal variable (standards can only be ranked). We therefore use an ordered logit estimator for the cross-sectional sample. For the panel model, we use a linear estimator with country- and year-specific fixed effects as there is no fixed effects ordered logit estimator. A positive and statistically significant variable coefficient means that a higher value of the variable is associated with a higher value of the dependent variable, i.e. a more stringent standard. The estimation sample covers up to 147 countries. It excludes all developed countries and EU member states (i.e. Canada, the US, Iceland, Norway, Switzerland, Japan, Australia, New Zealand and the EU-27 are omitted). However, these economies are included in the creation of the export-weighted spatial lag variable, because it is particularly exports to these higher-regulating markets which are hypothesised to exert a ratcheting-up effect on developing countries' domestic standards.

Recall that for the cross-sectional sample the value of the dependent variable refers to the year 2008. To mitigate potential reverse causality, the explanatory variables capture average values of the five-year period between 2003 and 2007.[13] A five-year average was taken as the sectoral FDI variable had many missings in some years and averaging over a number of years prevented a substantial loss of observations. For the panel models, all explanatory variables are lagged by one year.

Formally, we estimate variants of the following model:

$$y_{it} = \beta_1 \sum_k w_{ikt-1}^{auto-exports} y_{kt-1} + \beta_2 \ln FDIstock_{it-1}^{auto-sector} + \beta_3 \ln GDPpc_{it-1} + \beta_4 \ln Automobiles_{it-1}$$

$$+\beta_5 \%urban_{it-1} + \beta_6 trade / GDP_{it-1} + \beta_7 FDIstock / GDP_{it-1} + u_{it} \, ,$$

where i stands for the focal country and k stands for other foreign countries, t stands for time, y_i is the dependent variable, i.e. emissions standards, coded as either 0, 1, 2, 3 or 4, $\sum_k w_{ikt-1}^{auto-exports} y_{kt-1}$ is the export-weighted spatial lag variable,[14] $\ln FDIstocks_{it-1}^{auto-sector}$ is (the natural log of) FDI stock in the automotive sector, $\ln GDPpc_{it-1}$ is (the natural log of) GDP per capita, $\ln Automobiles_{it-1}$ is (the natural log of) the existing stock of automobiles on a country's roads, $\%urban_{it-1}$ is the share of the population living in cities, $trade / GDP_{it-1}$ is general trade openness and $FDIstocks / GDP_{it-1}$ is general FDI openness as measured by FDI stocks. The u_{it} variable represents a stochastic error term. Note, for the cross-sectional sample, there is no time dimension.

Results

Table 2 shows our cross-sectional estimation results. We begin with a model that excludes all control variables other than per capita income (model 1). We find that the automobile export-weighted spatial lag variable has a positive and statistically significant coefficient sign. That is, consistent with accounts of trading-up, our results indicate that developing countries which export a greater value of automobiles and related components to countries with more stringent emission standards over the period 2003 to 2007 themselves have more stringent emission standards in 2008. Our estimations also lend support to investing-up in automobile emission standards. The estimated coefficient for the FDI variable is positive and statistically significant, suggesting that developing countries have more stringent emission standards if they are hosts to larger stocks of FDI in the automotive sector. As expected, and consistent with past evidence, emission standards are also higher in richer countries.

Model 2 additionally includes the number of existing automobiles on a country's roads as a control variable, which leads to a reduction in sample size as data for this variable are not available for all countries. It is positively and statistically significantly correlated with the stringency of domestic automobile regulations. To the extent that passenger car numbers can be taken as a proxy for internal market size, our findings indicate that developing countries with larger markets for automobiles exhibit a greater propensity to adopt more demanding tailpipe emission standards. Whilst keeping its expected positive sign, the estimated GDP p.c. coefficient becomes statistically insignificant in model 2. The reason for this change is the substantial correlation between per capita income and the number of passenger cars: richer countries have more automobiles.[15] The coefficient sizes of our main variables of interest become smaller in model 2, but they remain not only statistically significant, but also substantively important. Of the two, the export-weighted spatial lag variable has the stronger effect. A one standard deviation increase in the spatial lag variable raises the odds of emission standards being more stringent by one unit (e.g. Euro 2 equivalent instead of Euro 1 equivalent) by 90.2 percent, whereas a similar one standard deviation increase in the FDI variable raises these odds by 44.7 percent.

In model 3, we add *%urban* to the estimation model. We do not find that a higher share of the population living in urban areas has an effect on emission standards that is statistically significantly different from zero. As with GDP p.c., however, the urban share is highly correlated with the total number of automobiles operating in a country. In model 4, we add the general trade and investment openness variables to the estimations. Neither type of general openness appears to contribute to the adoption of more stringent vehicular emission standards in our developing-country sample. Our main explanatory variables capturing trading-up and investing-up effects remain statistically significant in model 3, but only the export-weighted spatial lag variable remains significant in model 4.

Table 3 presents our fixed effects panel estimation results. These provide a tougher empirical test for our hypotheses. The country fixed effects, which account for unobserved heterogeneity across countries, absorb all between differences such that the estimations in table 3 are based on variations in countries over time only. Despite the inclusion of country fixed effects and year fixed effects, the export-weighted spatial lag variable is positive and statistically significant in all models. Thus, higher foreign standards in a country's major destinations for its automobile and related component exports are associated with higher domestic emission standards the following year. This result upholds even if we also include the temporally lagged dependent variable into the estimations (results not shown). No other variable is statistically significant except general FDI openness in model 4. Note, in particular, that the sectoral FDI variable never assumes statistical significance. Yet this was expected, since this variable has many gaps over such a long period of time which had to be filled with zeros to avoid a tremendous loss of observations, and is not really suited for panel estimation. This should caution against an interpretation of the results in table 3 as providing evidence against investing-up effects.

Conclusions

The idea that domestic environmental standards in low-regulating countries might ratchet-up closer to levels found in higher-regulating ones as a result of economic integration have frequently been used as a counter-weight to arguments that economic globalisation gives rise to downward convergence in environmental standards (Prakash and Potoski 2006; Vogel 1995). Yet, at least in the case of public environmental policy, large-N, quantitative evidence for upwards convergence has largely rested on geographically and sectorally aggregated analyses. Our goal in this article has been to subject the thesis of integration-driven ratcheting-up – a phenomenon described as the California effect – to far greater scrutiny using a research design which features more refined measures of economic integration.

Using the example of automobile emission standards, our results provide unique, geographically and sectorally disaggregated large sample support for the existence of a cross-border trading-up effect. We show that developing countries whose major automobiles and related components export markets have more stringent automobile emission standards are themselves more likely to have more stringent emission standards. Existing spatially disaggregated, large-N evidence for these dynamics is restricted to private environmental standards (Albuquerque et al. 2007; Perkins and Neumayer 2010; Prakash and Potoski 2006). Our estimations extend these results, strongly indicating that trading-up operates in the case of public environmental standards, too.

The finding that automotive exports to markets with higher emission standards should propel the adoption of more stringent standards domestically is entirely plausible. Market access to more stringently regulated economies requires exporting vehicle manufacturers to produce vehicles with superior environmental performance (Murphy 2004). As export volumes grow, so it may be in firms' interests for domestic standards to be harmonised closer to levels found in their major foreign markets, not least because producing similar vehicles and their components for both home and export markets should allow manufacturers to maximise economies of scale (Vogel 2000). It is also possible that trading-up may arise for other reasons unrelated to scale economies. The export of emissions-relevant components and vehicles to high-regulating markets demonstrates the capability of vehicle manufacturers to produce cars with superior emissions performance for the local market. It may therefore accelerate calls for regulatory tightening from domestic actors (such as environmental NGOs) with pre-existing interests in greater environmental protection, as well as making government regulators less reticent about setting more stringent emission standards.

Another important result regards inward FDI which has received very little attention in the existing literature. We provide evidence that host developing countries which receive more FDI in their automotive sector are, all else equal, more likely to have more stringent emission standards. We would caveat this statement by noting that FDI only emerges as a positive correlate of regulatory stringency in our cross-sectional estimations, although shortcomings of the time-series data mean that only limited weight should be placed on the insignificant coefficient in our panel estimations. We would also note that our FDI variable cannot account for the level of regulatory standards in the countries from which the FDI originates or where TNCs operate. Yet the fact that TNCs originate or else operate in a range of countries where emissions standards are likely to be more stringent than those in host developing countries tentatively suggests that this shortcoming of our empirical research design does not undermine our basic interpretation of the FDI result. A number of authors have been highly critical about the supposed environmental gains from FDI suggesting that, in certain cases, TNCs may even mobilise to prevent regulatory tightening in developing countries (Clapp 2001; Gallagher and Zarsky 2005; Madeley 2008). Our study would suggest that, at least in the case of automobile emission standards, these fears are not confirmed. The presence of TNCs, according to our estimations, appears to be conducive to the tightening of environmental product standards.

A number of factors might explain our result for FDI. All of the major TNCs manufacture vehicles equipped to comply with stringent standards for sale in higher-regulating developed economies. Moreover, even though they may not deploy their most advanced technology in certain developing countries, they may nevertheless transfer technology which is beyond compliance. This stems from the fact that TNCs may find it financially optimal from a corporate-wide perspective to transfer similar technology across a range of countries – and vehicles will be configured so that they can comply with the most stringent standard in any one of these markets.

Yet because their environmentally-superior vehicles may be more expensive to produce, and because higher environmental standards may disadvantage indigenous producers in developing countries, foreign TNCs have strong incentives to create a level playing field by lobbying for upwards harmonisation (Bennett 2001; Garcia-Johnson 2000). As with exports, inward FDI may also contribute to ratcheting-up by lowering compliance costs in that foreign vehicle manufacturers, suppliers and consultants bring technological knowledge, capabilities and hardware developed through costly technological effort elsewhere. The local presence of TNCs who operate in high-regulating markets, and therefore have the capabilities to produce vehicles with higher levels of environmental performance, may also alter domestic perceptions of feasible environmental standards amongst regulators, NGOs, etc.

Although instructive, the present study is not the last word on how economic integration influences domestic public environmental regulation. Our findings only cover product standards governing a single sector, i.e. automobiles. They say nothing about whether trading- or investing-up operate for environmental product standards in other sectors. Moreover, our study says nothing about how exports or FDI influence process or ambient environmental standards, for which the conceptual case for a race-to-the-bottom/regulatory chill is more persuasive (Scharpf 1997). Previous evidence regarding the influence of trade on such standards is mixed (Arts *et al.* 2008; Cao and Prakash 2010; Knill and Tosun 2009), while the literature has largely ignored the role of FDI. An important task for future research is to investigate whether ratcheting-up dynamics operate for process and ambient categories of environmental standards for both international trade and investment, using a research design that uses direct measures of public regulatory stringency, sectorally disaggregated data, and a large sample of countries.

Finally, despite the fact that our findings suggest that economic integration may catalyse the diffusion of environmentally superior innovations, it is worth noting that economic globalisation may be something of a double-edged sword. Trade and investment might well be instrumental in strengthening domestic environmental regulatory stringency in developing countries. Yet the very same forms of integration may contribute directly and indirectly to growing economic scale which may overwhelm any “gains” made from increased technological environment-efficiency brought about by regulatory tightening. For automobiles, this would mean that any emission reduction from more pollution-efficient cars could be more than offset by a larger total number of vehicles. It is far beyond the scope of this article to analyse these net pollution outcomes. Yet these considerations should caution against a simplistic reading of our findings to the effect that globalisation is necessarily “good” for environmental sustainability.

Endnotes

[1] Vogel (1995) acknowledges that economic integration can force countries to lower standards, although argues that the ratcheting-up effect has tended to predominate, especially for product standards.

[2] Also known as private environmental standards and voluntary initiatives.

[3] For simplicity, we often refer to the EU, even if before 1993 the supra-national institution was formally known as the European Community.

[4] Note, emission limit values do not apply to in-use vehicles, but form part of vehicles' 'homologation' requirements, which specify various technical standards that type models must meet in order to be legally approved for domestic sale.

[5] The EU itself first adopted passenger car emission standards in 1970, drawing from United Nations Economic Commission for Europe (UNECE) standards of the time (Greening 2001)

[6] Euro standards have been mandatory for all members of the EU. Many of the later entrants adopted Euro-type emission standards prior to their membership.

[7] Note, Tier 2 only fully came into force for all gasoline-fuelled passenger cars in 2007.

[8] Cross-market standardisation does not mean that vehicles sold in different countries will be identical because manufacturers may configure aspects of standard base-engine technology to suit local conditions, including fuel quality, regulatory requirements and road conditions. Moreover, after-treatment technologies (i.e. catalytic converters) will generally be configured to suit regulatory requirements in individual countries, not least because higher efficiency devices are significantly more costly to manufacture.

[9] Results uphold if additionally we include the temporally lagged dependent variable to control for common shocks and common trends.

[10] Note, where countries specify different requirements for (i) imported and (ii) locally produced vehicles, we took the latter.

[11] For example, US standards have specified comparatively more stringent requirements for NOx, whereas the EU's recent standards have been comparatively more stringent for CO.

[12] Harmonized System Code HS-87.

[13] Values of 2008 could not be included due to lack of data for the explanatory variables.

[14] Recall that the spatial lag variable is not row-standardized. Since vehicle and vehicle components run from a minimum of zero to a maximum of 2.32e+11, we divide the resulting spatial lag variable by 1e+11. Naturally, this affects the coefficient size only.

[15] We have tested for a non-linear effect of income with a squared and a cubed model specification, but found no evidence for such a non-linear effect.

References

Albuquerque, P., Bronnenberg, B. J. and Corbett, C. J. (2007) 'A spatiotemporal analysis of the global diffusion of ISO9000 and ISO14000 certification', *Management Science* 53(3): 451-468.

Arts, B., Liefferink, D., Kamstra, J., and Ooijevaar, J. (2008) ‘The gap approach: What affects the direction of environmental policy convergence?’, in K. Holzinger, C. Knill and B. Arts (eds), *Environmental policy convergence in Europe: The impact of international institutions and trade*, Cambridge: Cambridge University Press: pp.196-226.

Bach, D. and Newman, A. L. (2007) 'The European regulatory state and global public policy: Micro-institutions, macro-influence', *Journal of European Public Policy* 14(6): 827-846.

Bauner, D. and Laestadius, S. (2003) 'The introduction of the automotive catalytic converter in Chile', *Journal of Transport Economics and Policy* 37(2): 157-199.

Beise, M. and Rennings, K. (2005) ‘Lead markets and regulation: A framework for analyzing the international diffusion of environmental innovations’, *Ecological Economics* 52(1): 5-17.

Bennett, C. J. (1991) ‘Review article: What is policy convergence and what causes it?’, *British Journal of Political Science* 21: 215-233.

Bernauer, T. and Caduff, L. (2004) 'In whose interest? Pressure group politics, economic competition and environmental regulation', *Journal of Public Policy* 24(1): 99-126.

Birdsall, N. and Wheeler, D. (1993) ‘Trade policy and industrial pollution in Latin America: Where are the pollution havens?’ *Journal of Environment and Development* 2(1): 137-149.

Boehmer-Christiansen, S. and Weidner, H. (1995) *The politics of reducing vehicle emissions in Britain and Germany*. London: Pinter.

Busch, P.-O. and Jorgens, H. (2005) 'The international sources of policy convergence: Explaining the spread of environmental policy innovations', *Journal of European Public Policy* 12(5): 860-884.

CAI-Asia (2009) *Emission standards for new light-duty vehicles (as of April 2009)*, Pasig City: Clean Air Initiative - for Asian Cities.

Cao, X. and Prakash, A. (2010) 'Trade competition and domestic pollution: A panel study, 1980-2003', *International Organization* 64(3), forthcoming.

Clapp, J. (2001) *Toxic exports: The transfer of hazardous wastes and technologies from rich to poor countries*. Ithaca: Cornell University Press.

Cole, M. A., Elliott, R. J. R. and Fredriksson, P., G. (2006) 'Endogenous pollution havens: Does FDI influence environmental regulations?', *The Scandinavian Journal of Economics* 108(1): 157-178.

CONCAWE (2006a) *Motor vehicle emission regulations and fuel specifications - part 2 historic review (1996-2005)*, Brussels: CONCAWE.

CONCAWE (2006b) *Motor vehicle emission regulations and fuel specifications appendix to part 1 2004/2005 update*, Brussels: CONCAWE.

Continental (1999) *Worldwide emission standards and related regulations*, Regensburg: Continental Automotive GmbH.

Corbett, C. J. and Kirsch, D. A. (2001) 'International diffusion of ISO 14000 certification', *Production and Operations Management* 10(3): 327-342.

Damania, R., Fredriksson, P. G. and List, J. A. (2003) 'Trade liberalization, corruption, and environmental policy formation: Theory and evidence', *Journal of Environmental Economics and Management* 46(3): 490-512.

Dasgupta, S., Mody, A., Roy, S. and Wheeler, D. (2001) 'Environmental regulation and development: A cross-country empirical analysis', *Oxford Development Studies* 29(2): 173-187.

Delphi (2009) *Worldwide emission standards: Passenger cars & light duty trucks,* Michigan: Delphi.

Dicken, P. (2007) *Global shift: transforming the world economy*, 4th Edition. London: Sage Publications.

Drezner, D. (2005) 'Globalization, harmonization, and competition: The different pathways to policy convergence', *Journal of European Public Policy* 12(5): 841-859.

Falkner, R. (2006) 'International sources of environmental policy change in China: The case of genetically modified food', *The Pacific Review* 19(4): 473-494.

Gallagher, K. P. and Zarsky, L. (2005) 'No miracle drug: Foreign direct investment and sustainable development,' in L. Zarsky (ed). *International investment for sustainable development: Balancing rights and rewards,* London: Earthscan: 13-45.

Garcia-Johnson, R. (2000) *Exporting environmentalism: U.S. multinational chemical corporations in Brazil and Mexico*. London: MIT Press.

Genschel, P. and Plumper, T. (1997) ‘Regulatory competition and international co-operation’, *Journal of European Public Policy* 4(4): 626-642.

Hagner, C. (2000) 'European regulations to reduce lead emissions from automobiles – did they have an economic impact on the German gasoline and automobile markets?', *Regional Environmental Change* 1(3): 135-151.

Hao, J., Hu, J. and Fu, L. (2006) 'Controlling vehicular emissions in Beijing during the last decade', *Transportation Research Part A: Policy and Practice* 40(8): 639-651.

Haščič, I., De Vries, F. P. and Johnstone, N. (2009) 'Effects of environmental policy on the type of innovation: The case of automotive emission-control technologies', *OECD Journal: Economic Studies* 1: 41-58.

Heyes, A. (2009) 'Is environmental regulation bad for competition? A survey', *Journal of Regulatory Economics* 36(1): 1-28.

Hilton, F. G. (2006) 'Poverty and pollution abatement: Evidence from lead phase-out', *Ecological Economics* 56(1): 125-131.

Hoberg, G. (1991) 'Sleeping with an elephant: The American influence on Canadian environmental regulation', *Journal of Public Policy* 11(1): 107-131.

Holzinger, K. and Knill, C. (2005) ‘Causes and conditions of cross-national policy convergence’, *Journal of European Public Policy* 12(5): 775-796.

IRF (2009) *World road statistics 2009 - Data 2002-2007,* Geneva: International Roads Federation.

Jänicke, M. and Jacob, K. (2004) 'Lead markets for environmental innovations: A new role for the nation state', *Global Environmental Politics* 4(1): 29-46.

Jenkins, R. (2000) *Industry and environment in Latin America*. London: Routledge.

Knill, C. and Tosun, J. (2009) ‘Hierarchy, networks, or markets: How does the EU shape environmental policy adoptions within and between its borders?’, *Journal of European Public Policy* 16(6): 873-894.

Knill, C., Sommerer, T. and Holzinger, K. (2008) ‘Degree and direction of environmental policy convergence: Analysis of aggregate data,’ in K. Holzinger, C. Knill and B. Arts (eds), *Environmental policy convergence in Europe: The impact of international institutions and trade*, Cambridge: Cambridge University Press: pp.98-143.

Koehler, D., A. (2007) 'The effectiveness of voluntary environmental programs: A policy at a crossroads?', *Policy Studies Journal* 35(4): 689-722.

Körber, A. (1998) ‘Why everyone loves Flipper: The political-economy of the U.S. dolphin-safe laws’, *European Journal of Political Economy* 14: 475-509.

KPMG (2008) *The automotive industry in Central and Eastern Europe* KPMG International.

Lall, S. (1992) 'Technological capabilities and industrialization', *World Development* 20(2): 165-186.

Lazer, D. (2001) 'Regulatory interdependence and international governance', *Journal of European Public Policy* 8(3): 474-492.

Liefferink, D., Arts, B., Kamstra, J. and J. Ooijevaar (2009) ‘Leaders and laggards in environmental policy: A quantitative analysis of domestic policy outputs’, *Journal of European Public Policy* 16(5):677-700.

Lovely, M. and Popp, D. (2008) *Trade, technology, and the environment: Why have poor countries regulated sooner?*, NBER Working Paper No. 14286, August 2008, Cambridge, MA: National Bureau of Economic Research.

Madeley, J. (2008) *Big business, poor peoples: How transnational corporations damage the world's poor*, Updated edition. London: Zed Books.

Murphy, D. D. (2004) 'The business dynamics of global regulatory competition,' in D. Vogel and R. Kagan (eds), *Dynamics of regulatory change: How globalization affects national regulatory policies*, London: University of California Press: 84-117.

Neumayer, E. and Perkins, R. (2004) 'What explains the uneven take-up of ISO 14001 at the global level? A panel-data analysis', *Environment and Planning A* 36(5): 823-839.

Neumayer, E. and Plümper, T. (2010) 'Model specification in the analysis of spatial dependence', *European Journal of Political Research,* 49 (3): 418-442.

OECD (1997) *Economic globalization and the environment*, Paris: OECD.

Orsato, R.J. and Wells, P. (2007). U-turn: The rise of the automobile industry. *Journal of Cleaner Production* 15: 994-1006.

Paterson, M. (2007) *Automobile politics: Ecology and cultural political economy*. Cambridge: Cambridge University Press.

Peake, S. (1997) *Vehicle and fuel challenges beyond 2000: Market impacts of the EU's Auto Oil Programme*, London: Pearson Professional.

Perkins, R. (2007) 'Globalizing corporate environmentalism? Convergence and heterogeneity in Indian industry', *Studies in Comparative International Development* 42(3): 279-309.

Perkins, R. and Neumayer, E. (2004) ‘Europeanisation and the uneven convergence of environmental policy: Explaining the geography of EMAS’, *Environment and Planning C* 22(6): 881-897.

Perkins, R. and Neumayer, E. (2005) 'The international diffusion of new technologies: A multitechnology analysis of latecomer advantage and global economic integration', *Annals of the Association of American Geographers* 95(4): 789-808.

Perkins, R. and Neumayer, E. (2010) 'Geographic variations in the early diffusion of corporate voluntary standards: Comparing ISO14001 and the Global Compact', *Environment and Planning A* 42(2): 347-365

Prakash, A. and Kollman, K. L. (2003) ‘Biopolitics in the EU and the U.S.: A race to the bottom or convergence to the top?’, *International Studies Quarterly* 47: 617-641.

Prakash, A. and Potoski, M. (2006) 'Racing to the bottom? Trade, environmental governance, and ISO 14001', *American Journal of Political Science* 50(2): 350-364.

Prakash, A. and Potoski, M. (2007) 'Investing up: FDI and the cross-country diffusion of ISO 14001 management systems', *International Studies Quarterly* 51(3): 723-744.

Princen, S. (2004) ‘Trading up in the transatlantic relationship’, *Journal of Public Policy* 24(1): 127-144.

Rodrik, D. (1997) *Has globalization gone too far?* Washington, D.C.: Institute for International Economics.

Rugman, A. M. and Verbeke, A. (1998) 'Corporate strategies and environmental regulations: An organizing framework', *Strategic Management Journal* 19(4): 363-375.

Scharpf, F. W. (1997) ‘Introduction: the problem-solving capacity of multi-level governance’, *European Journal of Public Policy* 4(4): 520-538.

Shin, S. (2004) 'Economic globalization and the environment in China: A comparative case study of Shenyang and Dalian', *The Journal of Environment Development* 13(3): 263-294.

Sommerer, T., Holzinger, K. and Knill, C. ‘The pair approach: What causes convergence of environmental polices?’ in K. Holzinger, C. Knill and B. Arts (eds), *Environmental policy convergence in Europe: The impact of international institutions and trade*, Cambridge: Cambridge University Press: pp.144-195.

Tewari, M. and Pillai, P. (2005) 'Global standards and the dynamics of environmental compliance in India's leather industry', *Oxford Development Studies* 33(2): 245-267.

Tienhaara, K. (2006) 'Mineral investment and the regulation of the environment in developing countries: Lessons from Ghana', *International Environmental Agreements: Politics, Law and Economics* 6(4): 371-394.

Timilsina, G. R. and Dulal, H. B. (2009) 'Regulatory instruments to control environmental externalities from the transport sector', *European Transport* 41: 80-112.

Umicore Automotive Catalysts (2009) *2009 global emission regulations*, Umicore Autocat USA Inc.

UN (2009) *Commodity trade statistics database (COMTRADE)*. New York: United Nations Statistics Division.

UNCTAD (2007) *Transnational corporations, extractive industries and development*. Geneva: United Nations Publications.

UNCTAD (2009) 'Foreign direct investment database', Geneva: UNCTAD.

Vogel, D. (1995) *Trading up: Consumer and environmental regulation in a global economy*. London: Harvard University Press.

Vogel, D. (1997) 'Trading up and governing across: Transnational governance and environmental protection', *Journal of European Public Policy* 4(4): 556-571.

Vogel, D. (2000) ‘Environmental regulation and economic integration’, *Journal of International Economic Law* 3(2): 265-279.

Walsh, M. P. (1999) *Motor vehicle standards and regulations around the world,* Arlington, Virginia.

Whalley, N. and Whitehead, B. (1994) 'It's not easy being green', *Harvard Business Review* 72(3): 46-52.

Wheeler, D. (2001) 'Racing to the bottom? Foreign investment and air pollution in developing countries', *The Journal of Environment and Development* 10(3): 225-245.

World Bank (2009) *World development indicators on CD-ROM*. Washington, D.C.: IBRD.

Young, O. R. (1969) ‘Interdependencies in world politics’, *International Journal* 24(4): 726-750.

Zarsky, L. (2002) 'Stuck in the mud? Nation states, globalization and the environment,' in K. P. Gallagher and J. Werksman (eds), *The Earthscan reader on international trade and sustainable development*, London: Earthscan: 19-44.

Table 1. EU Euro emission standards, g/km (gasoline vehicles)*

	Euro 1 (code = 1)	Euro 2 (code = 2)	Euro 3 (code = 3)	Euro 4 (code = 4)	Euro 5 (code = 5)
CO	2.72	2.20	2.30	1.00	1.000
$HC+NO_x$	0.97	0.50	—	—	—
HC	—	—	0.20	0.10	0.100
NO_x	—	—	0.15	0.08	0.060
PM	—	—	—	—	0.005**

Notes: * implementation date for new type approvals, compliance requirements for existing models typically lag one year; ** for gasoline direct injection (DI) engines only

Table 2. Cross-sectional estimation results (2008).

	model 1	model 2	model 3	model 4
$\sum_k w_{ik}^{auto-exports} y_k$	0.138**	0.0540**	0.0493**	0.0465**
	(0.0540)	(0.0242)	(0.0217)	(0.0203)
$\ln FDIstock_i^{auto-sector}$	0.320***	0.155**	0.135*	0.125
	(0.104)	(0.0786)	(0.0824)	(0.106)
$\ln GDPpc_i$	0.222*	0.254	0.536	0.580
	(0.128)	(0.223)	(0.368)	(0.373)
$\ln Automobiles_i$		0.846***	0.886***	0.906***
		(0.160)	(0.138)	(0.154)
$\%urban_i$			-0.0186	-0.0190
			(0.0193)	(0.0194)
$trade / GDP_i$				-0.00204
				(0.00472)
$FDIstock / GDP_i$				0.699
				(0.544)
Pseudo R-squared	0.188	0.319	0.323	0.329
Observations	147	112	112	110

Notes: The estimator is ordered logit. Robust standard errors in parentheses.

* statistically significant at .1 level, ** at .05 level *** at .01 level.

Table 3. Panel estimation results with country fixed effects (1993 to 2008).

	model 1	model 2	model 3	model 4
$\sum_k w_{ik}^{auto-exports} y_{kt-1}$	0.0226***	0.0222***	0.0222***	0.0217***
	(0.00447)	(0.00447)	(0.00447)	(0.00430)
$\ln FDIstock_{it-1}^{auto-sector}$	0.0440	0.0437	0.0437	0.0436
	(0.0444)	(0.0437)	(0.0437)	(0.0431)
$\ln GDPpc_{it-1}$	0.226	0.239	0.239	0.216
	(0.159)	(0.186)	(0.186)	(0.186)
$\ln Automobiles_{it-1}$		-0.0884	-0.0885	-0.0832
		(0.0566)	(0.0577)	(0.0562)
$\%urban_{it-1}$			-0.000494	0.00219
			(0.0181)	(0.0177)
$trade / GDP_{it-1}$				0.00193
				(0.00130)
$FDIstock / GDP_{it-1}$				0.00818**
				(0.00321)
Observations	2281	1970	1970	1923
Countries	151	134	134	130
R-squared (within)	0.343	0.359	0.359	0.369

Notes: The estimator is ordindary least squares with country and year fixed effects. Standard errors clustered on countries in parentheses.

* statistically significant at .1 level, ** at .05 level *** at .01 level.