Journal of European Public Policy 19:2 March 2012: 217–237

Routledge Taylor & Francis Group

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

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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 automobile emission standards are found to be associated with more stringent domestic emission standards. Investing-up dynamics are also apparent, with aggregate inward foreign direct investment into host developing economies' automotive sector increasing the likelihood of more stringent emission standards domestically.

KEY WORDS Automobiles; California effect; convergence; investing-up; standards; trading-up.

INTRODUCTION

Recent work concerned with the regulatory implications of globalization 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 harmonization, while developing on his idea of 'trading-up', scholars have hypothesized the existence of a similar 'investing-up' effect arising from foreign direct investment (FDI) (Garcia-Johnson 2000; Prakash and Potoski 2007).

Yet, although qualitative case studies have offered evidence for a California effect in public environmental policy (Tewari and Pillai 2005), findings from more generalizable analyses using large-sample, quantitative techniques have

Journal of European Public Policy
ISSN 1350-1763 print; 1466-4429 online
http://www.tandfonline.com
http://dx.doi.org/10.1080/13501763.2011.609725

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 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. Finally, while the influence of trade has received attention from a number of scholars, the role of FDI in ratcheting-up in public environmental policy remains largely unresearched 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 relevant environmental standards.

Empirically, we make use of a new global data set 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, but, conceptually, they should be especially susceptible to trading- and investing-up. This is because they constitute environmental product standards, the automotive sector is characterized by significant cross-border trade and investment, and manufacturers face strong economic incentives to harmonize product specifications across different markets (Scharpf 1997).

Unique to the literature, our contribution provides the first large-N, geographically disaggregated empirical support for a trading-up effect for public environmental standards. We thus find robust evidence that exports of automobiles and related components from developing countries to countries with more stringent auto emission standards are 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 THROUGH GLOBAL ECONOMIC INTEGRATION

Recent discussions about the California effect are part of a longer-standing debate about the extent to which globalization contributes to cross-national convergence (Holzinger and Knill 2005; 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 and the assumed costs of environmental regulation would stimulate national governments to lower domestic standards (the 'race-to-the-bottom' thesis) or else make them reluctant to raise standards (the 'regulatory chill' thesis) (Rodrik 1997).

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 harmonization.[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.

Trading-up via exports

The idea that exporting to higher-regulating economies raises domestic regulatory stringency has been popularized in the concept of trading-up (Prakash and Potoski 2006; Vogel 1997). Trading-up is said to arise from the presence of environmental product standards which, under World Trade Organization rules, can be used by national governments to ban non-compliant imports. Such 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 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; Lazer 2001).

The literature suggests that trading-up is most likely to take place when countries export to large, high-regulating markets (Beise and Rennings 2005; Drezner 2005; Vogel 1995). At a fundamental level, domestic firms should be more inclined to re-engineer their products for larger markets, since the

costs of doing so are more likely to be outweighed by additional export revenues (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 large, high-regulating markets, leading them to exert more pressure on governments to introduce similar standards domestically (Genschel and Plümper 1997).

What constitutes a 'large' market is open to interpretation. Vogel (1995) himself refers to individual economies that 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 harmonization is created by FDI which is said to create pressures for upwards convergence in environmental policy through a process of investing-up (Perkins and Neumayer 2010; Prakash and Potoski 2007). Many of the world's transnational corporations (TNCs) originate, or else variously operate, in high-regulating developed economies, and therefore have accumulated the capabilities to comply with more stringent environmental standards (UNCTAD 2007). Further, they are known to transfer their environmentally-superior 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 can face criticism from civil society if they are seen to deploy environmentally inferior technologies in host countries. In turn, the transfer of standardized, beyond-compliance technologies creates incentives for TNCs to lobby for the upwards harmonization 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 may be priced 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 may 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 harmonization, 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

Two streams of literature have provided evidence consistent with a cross-border California effect, understood as the ratcheting-up of domestic environmental standards towards levels found in a country's major high-regulating economic partners. The first is a qualitative case-study literature. Apposite here are several studies which have documented how Germany successfully exerted pressure on the European Commission during the 1980s to adopt more stringent auto emission standards across the forerunner to the European Union (EU), the European Community (EC). An important factor underlying German government support for tighter EC-wide standards was the fact that the country's vehicle manufacturers were major exporters to the higher-regulating US market, and therefore were already producing vehicles capable of complying with more stringent standards (Boehmer-Christiansen and Weidner 1995; Vogel 1997). Raising regulatory standards across the EC closer to US levels gave German firms a competitive advantage, at least in the short term, over some of their European rivals (Hagner 2000). More generally, case-studies have provided evidence that exports from certain lower-regulating developing countries to higher-regulating developed countries have encouraged domestic governments to adopt more stringent public environmental standards (Jenkins 2000; Tewari and Pillai 2005). There is also some empirical support for investing-up dynamics in developing countries – albeit largely in the case of private environmental standards (Garcia-Johnson 2000).

A second stream of literature uses large-N, quantitative methods. For a sample of 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. Sommerer *et al.* (2008) and Liefferink *et al.* (2009) find only ambiguous evidence that bilateral trade openness contributes to environmental policy convergence in a sample of largely European countries. 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. Among the few studies to analyse direct investment, Cole *et al.* (2006) show that inward FDI is positively correlated with the stringency of domestic lead standards, with the 'positive' effects of inward investment declining with increased corruption.

However, while providing more generalizable insights than case-study work, the above quantitative studies suffer from several important shortcomings which

restrict their usefulness in scrutinizing 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 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. Furthermore, although conceptual accounts of trading-up emphasize exports, past studies have tended to focus on all trade (i.e. aggregated imports and exports). Additionally, previous work has analysed sectorally aggregated trade and FDI data, rather than restricting itself to sectors most likely to affect regulations governing negative externalities relevant to the dependent variable under investigation.

Our contribution seeks to overcome these shortcomings by making use of a newly constructed data set which records the domestic stringency of public automobile emission standards for a large sample of countries. Moving beyond sectorally aggregated work, we restrict our analysis to trade and investment in the automotive sector. Moreover, advancing on previous geographically aggregated analyses, we construct what is known as a spatial lag variable for trade, allowing us to examine the extent to which exporting more automobiles and automobile components to markets with more stringent emission standards is associated with more stringent domestic auto standards. For FDI, we cannot do the same due to lack of data that are 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 introduction to standards

Our focus in the present paper is on a comparatively stringent set of emission standards, beginning with regulations equivalent to Tier 0 and Euro I, which came into force for new vehicles in the US and EU markets in 1987 and 1992, respectively.[2] These standards have subsequently been tightened in a series of incremental steps. 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.[3] 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. In order to comply with each of these respective tighter standards, manufacturers have had to invest in technological upgrades of their vehicles, typically both in terms of base-engines and after-treatment devices.

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 (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). 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 in some countries.

Our goal in the present paper is to investigate whether the adoption of these (more stringent) vehicle emission standards in developing countries has, as predicted by the California-effect thesis, been driven by exports to and inward investment from higher-regulating countries.

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 organize 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.

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. Manufacturing the same components, systems and/or entire vehicles engineered to comply with particular environmental regulations 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). Cross-market regulatory harmonization may therefore be in the commercial interests of certain firms.

Yet there are potential constraints on firms based in low-regulating markets producing beyond-compliance technology for domestic sale. 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 the 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 costlier to produce because of the more sophisticated base-engine and after-treatment components required (KPMG 2008; Peake 1997). Automotive firms marketing technology that is significantly beyond compliance may therefore struggle to compete against other companies who have advantages in producing compliance-only equivalents. This means that export-oriented

firms wishing to maximize scale economies for technology engineered to comply with higher standards have a strong incentive to level the playing field domestically, pressurizing national governments to set the regulatory bar closer to the level found in their major export markets.

We would expect these pressures to harmonize to be greater in countries which export more of their automobiles and automobile components to high-regulating countries (Beise and Rennings 2005). A larger volume of exports increases the importance for firms to achieve cost competitiveness in high-regulating markets by maximizing economies of scale for emissions-compliant vehicles and components. 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 maximizing scale economies for vehicles, components or systems engineered to comply with lower standards.

Exporting to higher-regulating markets may also give rise to ratcheting-up as governments take cues about the appropriateness of emission standards from their major export partners (Busch and Jorgens 2005; Jänicke and Jacob 2004). Additionally, 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 might additionally catalyse demands from environmental non-governmental organizations (NGOs) for tougher standards locally and make domestic regulators more willing to accede to these calls.

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 – 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. Still, a significant number 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 capable of producing engine-out emissions within the requisite limits.[4] 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 with exports, TNCs face constraints in deploying standardized, beyond-compliance technologies, including fuel quality and the higher cost of environmentally superior vehicles. 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 (cf. 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 superior internal compliance capabilities, as well as foreign suppliers and engineering consultants who can assist manufacturers with technological upgrading, may also promote ratcheting-up by convincing governments about the feasibility of regulatory tightening. Higher levels of FDI could additionally enhance the opportunities available to domestic NGOs to lobby for tighter standards, e.g. arguing that there are no technical barriers to achieving better 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.

RESEARCH DESIGN

Dependent variable

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 1993–2008, 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.[5] It is thus much more stringently specified. The data set of regulatory stringency was constructed using a number of different sources, including CAI-Asia (2009), CONCAWE (2006a, 2006b), Continental (1999), Delphi (2009), KPMG (2008), 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

Table 1 EU Euro emission standards, g/km (gasoline vehicles)[a]

	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[b]

[a]Implementation date for new type approvals, compliance requirements for existing models typically lag 1 year.
[b]For gasoline direct injection engines only.

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.[6] 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 Economic Commission for Europe (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 USA 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 the EU and the non-EU emission standards is difficult because: (a) vehicles are tested over different driving cycles; (b) their relative stringency varies across individual pollutants[7]; 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 (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[8] 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 (Plümper and Neumayer 2010).

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, it is worth noting that the vast majority of automotive FDI originates in developed economies with stringent regulations (Dicken 2007; UNCTAD 2007), and our sectorally refined approach is a marked improvement over the sectorally aggregated one taken in many previous studies (Cole *et al.* 2006; Lovely and Popp 2008).

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 (Dasgupta *et al.* 2001; Hilton 2006; Lovely and Popp 2008). Hence, citizens in wealthier countries are more likely to demand higher environmental quality, generating political impetus for standards which reduce automobile pollution (Liefferink *et al.* 2009). 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 better-placed to afford the higher relative costs of emissions-reducing technologies (Timilsina and Dulal 2009). 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 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). Conversely, a larger market could well act as an impediment to regulatory tightening, in that local economies of scale may make it commercially viable to produce country-specific base-engine designs for the domestic market (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 urban areas is likely to increase the 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. 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, thereby stimulating demand for similar environmental regulatory protections domestically (Busch and Jorgens 2005). Higher levels of cross-border trade and investment may generate greater technological dynamism and, therefore a greater capacity to upgrade domestic vehicles to comply with more stringent emission standards. Controlling for general trade and FDI openness is important to minimize 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 FDI 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 USA, 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 that are hypothesized 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 5-year period between 2003 and 2007.[9] A 5-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 1 year.

Formally, we estimate variants of the following model:

$$y_{it} = \beta_1 \sum_k w_{ikt-1}^{\text{auto-exports}} y_{kt-1} + \beta_2 \ln \text{FDIstock}_{it-1}^{\text{auto-sector}} + \beta_3 \ln \text{GDPpc}_{it-1} + \beta_4 \ln \text{Automobiles}_{it-1} + \beta_5 \%\text{urban}_{it-1} + \beta_6 \frac{\text{trade}}{\text{GDP}_{it-1}} + \beta_7 \frac{\text{FDIstock}}{\text{GDP}_{it-1}} + v_i + u_{it},$$

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, $\sum_k w_{ikt-1}^{\text{auto-exports}} y_{kt-1}$ is the export-weighted spatial lag variable,[10] $\ln \text{FDIstocks}_{it-1}^{\text{auto-sector}}$ is the natural log of the FDI stock in the automotive sector, $\ln \text{GDPpc}_{it-1}$ is the natural log of GDP p.c., $\ln \text{Automobiles}_{it-1}$ is the natural log of the existing stock of automobiles on a country's roads, $\%\text{urban}_{it-1}$ is the share of the population living in cities, trade/GDP_{it-1} is the general trade openness and $\text{FDIstocks/GDP}_{it-1}$ is the 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 and no country fixed effects v_i can be included.

RESULTS

Table 2 shows our cross-sectional estimation results. We begin with a model that excludes all control variables other than p.c. 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 exported a greater value of automobiles and related components to countries with more stringent emission standards over the period 2003–2007 themselves had 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

Table 2 Cross-sectional estimation results (2008)

	Model 1	*Model 2*	*Model 3*	*Model 4*
$\sum_k w_{ik}^{\text{auto-exports}} y_k$	0.138**	0.0540**	0.0493**	0.0465**
	(0.0540)	(0.0242)	(0.0217)	(0.0203)
ln $\text{FDIstock}_i^{\text{auto-sector}}$	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)
$\%\text{urban}_i$			−0.0186	−0.0190
			(0.0193)	(0.0194)
trade/GDP_i				−0.00204
				(0.00472)
FDIstock/GDP_i				0.699
				(0.544)
Pseudo R^2	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 0.1 level.
**Statistically significant at 0.05 level.
***Statistically significant at 0.01 level.

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. While 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 p.c. income and the number of passenger cars: richer countries have more automobiles.[11] 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 per cent, whereas a similar one standard deviation increase in the FDI variable raises these odds by 44.7 per cent.

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. 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 the general FDI

Table 3 Panel estimation results (1993–2008)

	Model 1	*Model 2*	*Model 3*	*Model 4*
$\sum_k w_{ik}^{\text{auto-exports}} y_{kt-1}$	0.216***	0.213***	0.213***	0.210***
	(0.0429)	(0.0431)	(0.0430)	(0.0419)
$\ln \text{FDIstock}_{it-1}^{\text{auto-sector}}$	0.193	0.178	0.179	0.151
	(0.198)	(0.198)	(0.198)	(0.192)
$\ln \text{GDPpc}_{it-1}$	0.214	0.225	0.224	0.209
	(0.156)	(0.182)	(0.182)	(0.184)
$\ln \text{Automobiles}_{it-1}$		−0.0787	−0.0785	−0.0756
		(0.0558)	(0.0568)	(0.0558)
$\%\text{urban}_{it-1}$			0.00113	0.00291
			(0.0179)	(0.0177)
trade/GDP_{it-1}				0.00188
				(0.00130)
$\text{FDIstock/GDP}_{it-1}$				0.00784**
				(0.00300)
Observations	2281	1970	1970	1923
Countries	151	134	134	130
R^2 (within)	0.345	0.360	0.360	0.368

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

**Statistically significant at 0.05 level.

***Statistically significant at 0.01 level.

openness in model 4. Note, in particular, 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 interpolation and, where totally missing, with imputation by the smallest observable amount to avoid a tremendous loss of observations, meaning that it is not really well-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 has frequently been used as a counter-weight to arguments that economic globalization gives rise to downward convergence in environmental standards (Prakash and Potoski 2006; Vogel 1995). 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 (Perkins and Neumayer 2004, 2010; Prakash and Potoski 2006). Our estimations extend these results, strongly indicating that trading-up operates in the case of public environmental standards, too.

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 many 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 mobilize to prevent regulatory tightening in developing countries (Clapp 2001). 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.

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 globalization 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 paper to analyse these net pollution outcomes. Yet these considerations should caution against a simplistic reading of our findings to the effect that globalization is necessarily 'good' for environmental sustainability.

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ACKNOWLEDGEMENTS

The authors would like to acknowledge the generous support of the UK'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 participants at the 2010 Royal Geographical Society and American Political Science Association meetings for their helpful and constructive comments.

NOTES

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 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.
3 Note, Tier 2 only fully came into force for all gasoline-fuelled passenger cars in 2007.
4 Cross-market standardization 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.
5 Results uphold if additionally we include the temporally lagged dependent variable to control for common shocks and common trends.
6 Note, where countries specify different requirements for (i) imported and (ii) locally produced vehicles, we took the latter.
7 For example, US standards have specified comparatively more stringent requirements for NO_x, whereas the EU's recent standards have been comparatively more stringent for CO.
8 Harmonized System Code HS-87.
9 Values of 2008 could not be included due to lack of data for the explanatory variables.
10 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.
11 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.

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