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

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Abstract

According to one line of argument, economic integration may lead to the ratcheting upwards of regulatory standards towards levels found in higher-regulating jurisdictions, a phenomenon referred to as the 'California effect'. Yet, at least in the case of public environmental policies, comparatively little systematic empirical work has been undertaken to examine whether international trade and investment with more stringently regulated countries leads to higher domestic environmental standards in lower-regulating economies. Our contribution seeks to fill this gap using a newly-constructed dataset measuring the stringency of domestic automobile emission standards. We find robust support for a trading-up effect in a sample of up to 147 developing countries: greater automobile and related components exports to countries with more stringent automobile emission standards are associated with more stringent domestic emission standards. Investing-up dynamics are also apparent, in that we find higher inward FDI in the automotive sector is associated with more stringent domestic automobile emission standards in host developing economies.

Automobiles, California effect, harmonisation, 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, whilst attracting considerable interest, comparatively little systematic empirical work has been undertaken to examine whether international trade and investment with more stringently regulated countries leads to a ratcheting upwards of domestic environmental standards in lower-regulating economies. This is particularly true of public environmental policies. In fact, with the exception of a number of qualitative case-studies, current understanding of California effect-type dynamics is largely restricted to private standards, i.e. voluntary codes-of-conduct (Albuquerque *et al.* 2007; Perkins and Neumayer 2010; Prakash and Potoski 2006, 2007).

A major reason for this gap is a basic lack of data. Unlike many private codes, comparable data on the stringency of public environmental regulations is simply not publicly available, at least for a large sample of countries. Precisely for this reason, studies have frequently had to rely on a number of indirect proxies when analysing aspects of regulatory stringency (e.g. Cao and Prakash 2010; Wheeler 2001). Our contribution seeks to overcome this gap, namely by constructing a new global dataset of automobile emission standards, which allows us to undertake a novel large-N, statistical test of whether the California effect operates across borders for a large sample of developing countries.

Automobile emission standards make a good test case because, 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. Indeed, a failure to find systematic evidence for a cross-border California effect in the automotive sector would cast considerable doubt over accounts of integration-driven ratcheting-up, not least for the reason that vehicular emission standards were a source of inspiration for the original thesis. Automobile emission standards also have analytic advantages in that they regulate a clearly defined product sector (i.e. automobiles). Thus a major benefit of our study is that we are able to make use of sectorally disaggregated data which only measure trade and investment in sectors most likely to affect the stringency of auto emission standards (i.e. automobiles and related components), thereby advancing on past work which has relied on data capturing all economic sectors (Cole *et al.* 2006; Lovely and Popp 2008).

Our contribution provides, to the best of our knowledge, the first large-N empirical support for cross-border regulatory dynamics consistent with a California effect involving unilateral public environmental policies. We 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 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

One reason why the California effect has proved controversial is that it contradicts earlier work which predicted that inter-state competition would stimulate national governments to lower their 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 predictions is 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 – at least for environmental product standards (Jänicke and Jacob 2004; Rugman and Verbeke 1998; Vogel 1995). Under certain circumstances, it is suggested that the benefits for certain 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 incentive for firms in country *i* wishing to export to higher-regulating markets *k* to re-engineer their products to standards found in the latter. 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 product 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).

However, there is no guarantee that domestic governments will raise environmental standards, particularly if the payoffs are not sufficiently high (Bernauer and Caduff 2004). For these reasons, scholars have stressed the importance of market size, arguing that larger markets provide stronger economic incentives for upwards harmonisation (Beise and Rennings, 2005; Drezner 2005; Falkner 2006; Vogel 1995). 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

A second form of economic integration implicated in a California effect at the cross-national level is constituted by inward FDI[2] (Garcia-Johnson 2000; Perkins and Neumayer 2009; Shin 2004). 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 may transfer their environmentally-superior technologies to foreign affiliates and subsidiaries in lower-regulating countries, creating incentives for TNCs to lobby for the upwards harmonisation of environmental standards (Garcia-Johnson 2000). These incentives derive from the fact that: (a) in the absence of higher standards, TNCs' beyond-compliance product technology 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 may well find it more costly to comply (Heyes 2009; Rugman and Verbeke 1998).

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 economic partners via trading-up and investing-up effects – has come from research which has analysed the diffusion of voluntary codes-of-conduct. [3] 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 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 largely 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).[4] 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.

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 literature also says comparatively little about the role of inward FDI as a driver for public environmental regulatory tightening.

Unfortunately, only a handful of large-N, quantitative studies have been undertaken which might provide more generalisable insights. 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. 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.

While these studies support the idea that trade and FDI raises the stringency of domestic public environmental policies, they suffer from two major shortcomings. 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. Moreover, although conceptual accounts of ratcheting-up emphasise exports, past studies have tended to focus on all trade (i.e. aggregated imports and exports). Another shortcoming of the literature is that it has focused on trade and FDI in all economic sectors, 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. We therefore make use of a newly-constructed dataset which records the domestic stringency of public automobile emission standards for a large sample of countries. We also 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 bilaterally disaggregated data, 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[5] – were first introduced in the US, Japan and various European[6] countries in the 1960s and 1970s (Hagner 2000). Early standards were comparatively weak. They were typically met with a number of modifications to base-engine designs and, in the US where regulatory standards have historically been more ambitious, the addition of basic catalytic converters (Mondt 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[7] markets in 1987 and 1992 respectively. These standards were far more technologically demanding, requiring more 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). 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. [8] 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. The result of these regulatory interventions is that tailpipe emissions of key pollutants (i.e.. CO, HC and NO_x) from new gasoline vehicles are now approximately 95% lower as compared to pre-control levels (Haščič *et al.* 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 (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.

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. 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 and 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 exports and inward investment ties.

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. 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 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-engine designs, configured with the same emissions control sub-systems (e.g. electronically-controlled multi-point fuel injection), as well as common after-treatment technologies (i.e. catalytic converters). Hence, rather than having to design, manufacture and configure different models for different countries, car producers can deploy a similar model for markets with equivalent emission standards.

When set in the context of earlier arguments about trading-up, these economic considerations suggest that vehicle manufacturers based in lower-regulating economies who export more to higher-regulating ones should favour raising domestic standards. Manufacturing similar vehicles for use in both home and foreign markets will reduce unit costs and, importantly, contribute to improved export competitiveness (Hagner 2000; Jänicke and Jacob 2004). Although firms located in low-regulating countries could achieve scale economies by producing beyond-compliance vehicles for the domestic market, two factors weigh against doing so. One is that vehicles fitted with more advanced base-engine and after-treatment technology 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 going beyond-compliance unilaterally is not always an option is that vehicles engineered to comply with more stringent emission standards are invariably more costly to produce (Peake, 1997; KPMG 2008). Hence, export-oriented vehicle manufacturers have a strong incentive to level the playing field domestically, pressurising national governments to set the regulatory bar at the level of their major export markets.

Indeed, doing so may provide export-oriented firms with a commercial advantage over their domestic competitors who predominantly sell to the local market, with the latter likely finding it more costly to engineer emissions compliant vehicles (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 would suggest that more stringently-regulated foreign markets account for a larger share of a country's overall production volume – and that economies of scale are greater for vehicles engineered to comply with higher emission standards. This is likely to increase the incentives to produce similarly specified vehicles for the domestic market, as opposed to producing smaller batches of environmentally-superior vehicles for foreign markets, and concentrating on maximising scale economies for vehicles 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 in benchmarking appropriate emission standards (Busch and Jorgens 2005; Jänicke and Jacob 2004). The very fact that beyond-compliance vehicles are being manufactured domestically may additionally catalyse demands from environmental NGOs (and other groups with similar interests) for similarly specified models locally. Indeed, the export of environmentally superior vehicles should also lower the costs of introducing higher standards domestically, making governments less reluctant to respond to these demands.

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. The majority of FDI in the automotive sector comes from high-regulating developed economies. And, even where FDI originates in developing countries, such investments will often come from TNCs who sell vehicles in developed-country markets. That TNCs already mass produce cars engineered to comply with more stringent standards means that they have incentives – arising from economies of scale and avoided duplication costs – to deploy similar technologies across their global or regional networks.

As with exports, TNCs face constraints in doing so, 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. 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, i.e. 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 convince governments about the feasibility of adopting higher standards. Similar to exports, FDI in the sector could also help to lower the costs of regulatory tightening, because (a) TNCs have ready access to "off-the-shelf" compliance technologies and (b) 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

Research Design

Dependent variable: regulatory stringency of automobile emissions

We take the value of regulatory stringency of gasoline vehicles for the year 2009 as our dependent variable. 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.[9] As of 2009, 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[10]; 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[11] 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).

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 stock 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 (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 direct investment, respectively, using data from World Bank (2009) and UNCTAD (2009).

Estimation model and sample

The dependent variable is an ordinal variable (standards can be ranked, but the variable is not cardinal). We therefore use an 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 the value of the dependent variable refers to the year 2009. To mitigate any potential reverse causality, the explanatory variables capture average values of the five-year period between 2003 and 2007.[12] 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.

Formally, we estimate variants of the following model:

$$y_i = \beta_1 \sum_k w_{ik}^{auto-exports} y_k + \beta_2 \ln FDI_i^{auto-sector} + \beta_3 \ln GDPpc_i + \beta_4 \ln Automobiles_i$$

$$+\beta_5 \%urban_i + \beta_6 trade / GDP_i + \beta_7 FDI / GDP_i + u_i ,$$

where *i* stands for the focal country and *k* stands for other foreign countries, y_i is the dependent variable, i.e. emissions standards, coded as either 0, 1, 2, 3 or 4, $\sum_k w_{ik}^{auto-exports} y_k$ is the export-weighted spatial lag variable, $\ln FDI_i^{auto-sector}$ is (the natural log of) FDI in the automotive sector, $\ln GDPpc_i$ is (the natural log of) GDP per capita, $\ln Automobiles_i$ is (the natural log of) the existing stock of automobiles on a country's roads, $\%urban_i$ is the share of the population living in cities, $trade / GDP_i$ is general trade openness and FDI / GDP_i is general FDI openness. The u_i variable represents a stochastic error term.

Table 2 provides summary descriptive variable information and a bivariate correlation matrix.

Results

Table 3 shows our 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 2009. 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. Emission standards are also higher in richer countries, as one would expect.

Model 2 additionally includes the number of existing automobiles on a country's roads as a control variable. 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 on the roads: richer countries have more automobiles (demand for automobiles is a normal, possibly even a luxury good, meaning that as incomes rise demand for automobiles goes up, possibly even more than proportionally so). 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. These latter results are interesting when considered alongside our main findings because they tentatively suggest that what matters is not overall levels of exposure to all other countries via transnational economic dependencies. Rather, ratcheting-up of domestic regulatory standards in developing countries would appear to be driven by more sectorally-specific linkages, i.e. those in the automotive sector. This is confirmed by the fact that, in both models 3 and 4, our main explanatory variables capturing trading-up and investing-up effects remain statistically significant with the expected positive coefficient signs.

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 pressures on environmental standards (Prakash and Potoski 2006; Vogel 1995). Yet, at least in the case of public environmental policy, claims of trading- and investing-up have largely rested on examples drawn from a small number of countries. Our goal in this article has been to subject the thesis of integration-driven ratcheting-up – a phenomena described as a California effect – to far greater scrutiny by using a research design featuring a large sample of low-regulating developing countries and that controls for additional factors which might explain uneven cross-national patterns of regulatory tightening.

Using the example of automobile emission standards, our results provide unique, large-N support for the existence of a cross-border California effect. We show that developing countries whose major export markets – as given by those economies to which they export more automobiles and related components – 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 also 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 with their major foreign markets, not least because producing similar vehicles for both home and export markets should allow manufacturers to maximise economies of scale. To the extent that exporting more to markets with higher regulatory standards may demonstrate the feasibility of regulatory tightening, and possibly lower the economy-wide adjustment costs, it might also increase governments' willingness to introduce more stringent standards domestically.

Another important result regards inward FDI. We provide unique 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 our FDI variable cannot account for the level of regulatory standards in the countries from which the FDI originates. Yet the fact that the vast majority of FDI in the automotive sector is likely to come from countries with high standards 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. TNCs already manufacture vehicles equipped to comply with more stringent standards for sale in higher-regulating economies in which they operate and may find it expedient to transfer the very same technology for sale in lower-regulating host economies. 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 (Garcia-Johnson 2000). As with exports, inward FDI may also contribute to ratcheting-up by lowering compliance costs, and raising domestic expectations of feasible environmental 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 – although we see no reasons to suspect that they might not (c.f. Greenhill *et al.* 2009). Moreover, our study says nothing about how exports or FDI influence process or ambient environmental standards, for which the case for a race-to-the-bottom/regulatory chill is potentially more persuasive. An important task for future research is to investigate whether ratcheting-up dynamics operate for these latter categories of environmental standards, 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 a strengthening of 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.

[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] Note, there are arguments as to why outward FDI might similarly have an investing-up effect, but the theoretical case for inward FDI is far stronger.

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

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

[5] 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.

[6] 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)

[7] 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.

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

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

[10] 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.

[11] Harmonized System Code HS-87.

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

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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. Summary descriptive variable information and bivariate correlation matrix.

Variable	Obs	Mean	Std. Dev.	Min	Max
y_i (Emission standards)	112	0.768	1.259	0	4
$\sum_k w_{ik}^{auto-exports} y_k$	112	3.580	16.569	0	130.876
$\ln FDI_i^{auto-sector}$	112	0.540	1.835	0	8.732
$\ln GDPpc_i$	112	7.204	1.366	4.623	10.320
$\ln Automobiles_i$	112	12.486	2.088	7.479	17.086
$\%urban_i$	112	50.508	23.283	9.72	100
$trade/GDP_i$	110	94.768	58.256	27.033	433.328
FDI/GDP_i	112	0.194	0.564	0	5.435

	1	2	3	4	5	6	7	8
1: y_i (Emission standards)	1							
2: $\sum_k w_{ik}^{auto-exports} y_k$	0.4788	1						
3: $\ln FDI_i^{auto-sector}$	0.4348	0.3144	1					
4: $\ln GDPpc_i$	0.3862	0.2272	0.247	1				
5: $\ln Automobiles_i$	0.6594	0.3889	0.3442	0.4117	1			
6: $\%urban_i$	0.3681	0.1788	0.1622	0.7943	0.4621	1		
7: $trade/GDP_i$	0.0413	-0.0718	0.1419	0.4417	-0.1079	0.3139	1	
8: FDI/GDP_i	0.0548	-0.0140	0.0574	0.0388	-0.0812	0.1805	0.2674	1

Table 3. Estimation results.

	model 1	model 2	model 3	model 4
$\sum_k w_{ik}^{auto-exports} y_k$	0.115***	0.0388**	0.0370**	0.0347**
	(0.0338)	(0.0167)	(0.0149)	(0.0144)
$\ln FDI_i^{auto-sector}$	0.380***	0.201***	0.194***	0.179*
	(0.110)	(0.0733)	(0.0730)	(0.109)
$\ln GDPpc_i$	0.258*	0.245	0.362	0.388
	(0.132)	(0.222)	(0.355)	(0.359)
$\ln Automobiles_i$		0.830***	0.842***	0.867***
		(0.156)	(0.141)	(0.159)
$\%urban_i$			-0.00781	-0.00771
			(0.0195)	(0.0192)
$trade / GDP_i$				-0.00132
				(0.00524)
FDI / GDP_i				0.630
				(0.421)
Pseudo R-squared	0.190	0.315	0.316	0.322
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.