Paper Title:

Regulatory Matters: Which Factors Matter in Regulating the Environment?

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I. Introduction

Pollution abatement strategies have been center stage in the developed world for close to four decades. Similar concerns are fast enveloping developing economies, especially those in Asia, that are growing at a rapid pace. One option is to follow what developed countries did. Advanced country studies (Vogel, 1995; Lanjouw and Mody, 1995; Popp, 2003) indicate that regulations restricting pollution induce a shift to more environment-friendly technologies. These studies suggest that some regulation is prerequisite for and perhaps an essential first step towards containing emissions. The present study focuses on factors that influence the diffusion and adoption of environmental regulations in developing countries. Understanding these factors may provide tools to directly or indirectly induce pollution control in these countries.

This essay specifically looks at adoption of automobile emissions regulations in four countries: China, India, South Korea, and Thailand. The rapid rate of urbanization makes air pollution an especially pertinent problem in certain pockets of the developing world. World Bank studies find that pollution levels in Asian mega-cities**,** such as Bangkok, Bombay, Jakarta, Manila and Seoul, exceed those in any city in industrialized countries (Kojima et al., 2000). In these countries, automobiles are the single biggest source of air-pollution in metropolitan areas. These nations have responded by adopting emissions regulations. What is interesting is that the regulations that these countries have adopted are more stringent than those that developed nations had at a similar stage of development (Figure 1). Indicating that a country's income level alone does not accord an adequate explanation of the phenomena as propounded by the Environmental Kuznets Curve (EKC) literature wherein environmental quality improvements are associated with higher levels of income (Grossman et al., 1995; Hilton et al., 1998).

[Figure 1 HERE]

The traditional role that regulations play in the developed world is one *drives technology.* Technology-driving standards are mandates that are technologically feasible but for which technology has not yet been developed. However**,** due to a lack of internal research and development (R&D) capacities in developing countries, I expect *access to technology* to play a pivotal role in enabling regulatory change. If

this holds true, technology might have a ratcheting effect on regulations, reversing the cause and effect sequence experienced in the developed world. To study the influence of access to technology I focus on factors such as *openness*, *trade considerations*, *foreign direct investment* and, existing *political institutions* in the adoption of regulations while controlling for population demographic and income.

Using data from interviews and secondary sources to trace regulatory processes, I find regulators in these countries impose regulations that aim to 'satisfice' rather than maximize emissions control. Given the environment of uncertainties, the information that is accessible and, constrained by computational capacities, regulators work with a 'bounded rationality' (Simon, 1955). They adopt regulations that can be met with demonstrated technologies, thereby reducing abatement costs that result from uncertainties in the invention process. Countries that are open to foreign trade, investment and collaborations, are able to access abatement technologies invented in advanced countries and thus able to adopt more stringent regulations than they otherwise would.

The rest of the paper is divided as follows. Section 2 reviews the literature and sets up the analytical framework, section 3 introduces the methodology, section 4 reviews emissions regulations in place and discusses augmenting policies, section 5 analyzes interviewee information in light of section 4 to infer causal relations and section 6 concludes.

II. Literature Review/ Theory

The adoption literature says that regulators are broadly guided by considerations of the benefits and costs of adopting a regulation. While these considerations may include infrastructural concerns like institutions and enforcement, regulators are expected to weigh the benefits of reduced pollution levels against the costs of abatement. A theoretical understanding of the factors that affect the demand for a better environment is well-established in the literature (Levinson and Hank, 1997; Grossman and Krueger, 1991). The literature focuses less on benefits from arresting environmental degradation as costs of a degraded environment are less amenable to quantification. This study therefore focuses on factors that reduce the costs of abatement while acknowledging the demand factors used in the conventional regulation literature.

One important cost is the cost of abatement technologies. Countries that regulated early devoted substantial resources to research and develop requisite technologies. There are two types of costs that late adopters can essentially avoid by adopting proven technologies. First, by using such technologies these new adopters can learn from and avoid the mistakes made by those who adopted earlier. For instance, the pace of regulations followed in the United States was so rapid that it forced manufacturers to design control systems that were not very durable (Crandall et al., 1986). Late adopters can avoid such technologies and the expensive consequences of their failures. The second factor that could reduce the cost of abatement is embedded in the notion of positive externalities or spillovers. A pecuniary spillover occurs when the cost of obtaining technologies is less than the cost of inventing it (Griliches, 1979). I expect such pecuniary spillovers to be especially important for developing countries as they have fewer resources available for R&D of abatement technologies. Therefore**,** by adopting technologies that have already been invented abroad, developing countries can reduce abatement costs.

The second set of literature that informs this paper consists of studies that look at international diffusion. Theories of international diffusion identify international trade (Coe and Helpman, 1995; Eaton and Kortum, 1996) and foreign direct investment (FDI) (Xu, 2000; Saggi, 1999) as carriers both of technological knowledge and of technologies embedded with knowledge. Hence, I expect both a country's trade and its investment policies to play an important role in increasing its access to technologies. The terms "access" and "accessibility" capture the idea that the technology is both available (with trade or FDI partner) and affordable, enabling developing countries to adopt regulations faster than they otherwise would.

Figure 2 schematically depicts the forces that impact regulatory stringency. The factors on the right-hand side, like income and pollution levels, drive the demand for regulations. These factors are policy-relevant and have conventionally been the focus of research. Oft ignored are the factors on the left of the stringency index that make abatement technologies known, accessible and potentially more affordable for a late adopter. These include trade with countries that have adopted regulations earlier and foreign investments by pioneer country automobile manufacturers.

[**Figure 2 HERE]**

Coe and Helpman (1996) find that trade creates access to intermediate goods like emissions control technologies. Such technologies developed abroad have positive spillovers for the importing country. First, if importing is less expensive than the cost of inventing, they get a pecuniary benefit (Griliches, 1979; Keller, 2001). Second, these goods could compete with the domestic industry and act as incentives to innovate (Sjoholm, 1996). Trade not only brings in such technologies but also enhances the flow of ideas (Eaton and Kortum, 1996) to countries which lack indigenous R&D. Lanjouw and Mody (1995) find that developing countries, especially in East Asia, often chose to obtain technologies embodied in pollution abatement equipment. However, other developing nations have adapted imported technologies to local conditions and still others have imported *disembodied* technologies like blue-prints and licenses. Thus, whether by acting as a building block or simply by making technology available at a lesser cost, trade increases the accessibility of cleaner technologies.

Foreign Direct Investment (FDI) is another important channel for the diffusion (Xu, 2000; Keller, 2001; Griliches, 1990) of technology. A multinational (MNC) automobile company investing in a subsidiary unit in a host country will tend to bring cleaner technologies with it. Esty and Gentry (1997) cite several reasons like the efficiency of having a single set of management practices and pollution control technologies besides visibility and liability, for the tendency of MNCs to bring in cleaner technology. These companies are therefore better equipped to meet regulations in this sector.

Others (Saggi,1999) argue that the central role in knowledge transfers belongs to an interaction between innovators (potential suppliers of technology) and those firms and entrepreneurs that seek to gain access to newer technologies, either through: (a) costly imitation, (b) technology licensing or (c) by forming collaborations with innovators. These then are intentional actions taken by people in response to market incentives, implying that a fair part of technology transfer is indeed endogenous to the system. Therefore, an economy open to foreign investment and collaborations would be more likely to adopt stricter regulations than one that is less so. Such outcome is also consistent with the intuition of an "epidemic effect" (Griliches, 1995; Karshenas and Stoneman, 1993) wherein information shared between an

"infected" population (one that has already adopted) and non-adopters that it comes into contact with instigate adoption.

Advanced country literature (Vogel, 1995) also suggests that an export market is an incentive for adopting stricter regulations. Germany and Japan, for instance, were motivated to adopt U.S. automobile standards to get access to the U.S. market, whereas developing countries did not have a similar incentive. Accordingly, in this study, I would also expect to see a similar ratcheting of standards if a country exports to countries with higher standards. Entrepreneurs in such countries would be motivated to acquire technologies to enable them to meet export market needs. Developing country entrepreneurs may develop or acquire necessary know-how through collaborations or imports to meet export country regulations. Acquiring expertise in these technologies can in turn make it easier for the home country to move to stricter standards. The intuition is that technology gets cheaper and better as time passes after its initial introduction, lowering the threshold of adoption to encompass more late adopters.

In light of the theoretical framework above, this study expects that the likelihood of a country to adopt more stringent regulations increases when:

- H1: it opens up to trade with pioneering countries, as this brings in goods embodied with such technologies, as well as encourages the flow of ideas;
- H2: it opens up foreign investments in the automotive sector, as this encourages flow of technological know-how;
- H3: it has an export market that requires compliance with stricter regulations than at home, as this motivates domestic manufacturers to acquire advanced abatement equipment.

III. Methodology

As hypothesized above**,** I expect trade and investment policies affecting the automobile industry to play a pivotal role. To test my hypotheses, I analyze the timing of regulations vis-à-vis augmenting policy measures taken by governments in South Korea, India, China, and Thailand. Each of the four countries differs in their market-focus and trade/investment policies. The key differences between the four countries are dealt with in more detail in Section IV below.

In the following sections, I review the history of regulations in the four countries and policies affecting the automobile industry to chalk out a timeline of events. I then use data from interviews with

policy-makers, researchers and automobile manufacturers to analyze the impact of industry characteristics and augmenting policy measures on adoption of regulations. In-depth interviews were conducted in India and South Korea. The policies affecting the automobile industry in these two countries are divergent, representing two opposing cases. To ensure a balanced representation of events and processes the interviewees include people directly involved in policy-making, implementation, research and development, as well as compliance. Table 1 gives a profile of people interviewed in the two countries.

[Table 1 HERE]

The interviews were semi-structured with a focus on regulation and compliance. In the interviews, I ask two types of questions[1]. The first set focused on the major concerns that regulators have in adopting regulations. This set of questions aims at understanding what regulators and manufacturers perceive as the driving forces behind regulations. The second set focused on technological considerations and incentives for compliance. Specific questions directed at manufacturers focused on the process of procuring technologies and compliance issues, while those for regulators focused on the regulatory processes. Additionally, I spoke with researchers working in technical, as well as environmental research institutes. Verbal information**,** as well as documentation provided by interviewees is used in the analysis.

China and Thailand are used as controls in this study, as they share characteristics with India and South Korea respectively. I primarily use secondary data sources in these two countries. Contemporary literature on the automobile industry provides some insight into the processes in China and Thailand for the analysis. I use this information to compare and contrast with what I find in countries where interviews were conducted to discern patterns in regulatory decision making.

[1] The interview protocol can be made available on request.

IV. Background

(a) Brief history of Emissions Regulations and control technologies

Automobile emission standards are numerical limits set by a governing body or agency to regulate the amount of criteria pollutants such as oxides of nitrogen (NO_X) , hydro-carbons (HC), carbon-monoxide (CO) and volatile organic compounds (VOCs) emitted through automobiles' tailpipes or leaking out of their engines. These pollutants pose visibility hazards and are noxious to health. For instance, NO_X not only increases respiratory illnesses but also reacts with HC in sunlight to form a photochemical smog affecting visibility.

The California Air Resources Board (CARB) first imposed regulations in 1966 restricting emissions from automobiles that added to already heavy smog. Subsequently, the U.S. Environmental Protection Agency (EPA) issued directives for controlling crankcase emissions from vehicles throughout the U.S., following the Federal legislation of the Clean Air Act (CAA, 1970). The 1970 regulations required a 90% reduction in CO and HC emissions from the uncontrolled levels of 1968 (Faiz et al., 1996). These regulations however, were adjusted in 1977 to delay, relax and adopt standards in a phased manner as the required technologies were not available.

Each step in regulatory stringency required new emission control technologies to meet the set mandates. The 1981 emission limits called for oxidation catalysts of precious metals like rubidium, platinum and rhodium to convert pollutants to CO_2 and water in carburetor engines. For more efficient fuel distribution and efficient working of the catalytic converters (CCs), manufacturers equipped new vehicles with fuel-injection systems. Fuel-injectors, coupled with the exhaust gas recirculation (EGR) technique, reduce peak combustion temperatures and reduce formation of NO_X. Subsequently, CAA amendments in 1990 further tightened emissions standards. The period between 1990 and 1994, also known as the Tier 0 level of regulations, included stringent NO_X reductions as well. To increase NO_X reductions, the design of new vehicles incorporated catalytic converters with three-way catalysts. New and tighter limits (Tier 1) introduced in 1994 forced more innovative control systems. By 1996, technologies in use could convert approximately 96% of consumed fuel emissions to its harmless components (Homeister, 2001). By 2004,

Tier 2 regulations requiring a further 50% reduction of pollutants were in place. To meet these standards, CCs had to be monitored and air-fuel ratios controlled with advanced technologies like on-board diagnostics (OBD). By introducing electronic control units (ECU) and sensors to maintain engine temperature in their cars, manufacturers increased the conversion efficiency of catalysts. At present, control technologies have progressed in both durability and efficiency from the first generation catalytic converters (AECC, 2000).

The lure of the U.S. market also motivated Japanese and German manufacturers to meet the U.S. emissions standards (Vogel, 1995). Germany and Japan adopted regulations subsequently. However, there are some variations in requirements in these countries. Japan imposed regulations two years after California in 1969. The directives of the UN Economic Commission for Europe (UN/ECE) form the basis of the Euro standards followed by countries in the European Union (EU). While both Japan and the U.S. followed numerous incremental tightening of standards, EU[1] nations made a spectacular jump in stringency levels in 1986 to catch up (Figure 3). This jump was perhaps facilitated to some extent by technologies made known by the pioneering countries. Presently, the U.S. has the most stringent regulations, followed by Germany (and countries that joined the EU) and Japan. Regulatory stringencies in the pioneer countries, however, are not directly comparable as they use different driving cycles and units of measure. To enable comparison between the U.S., Japanese and EU standards, a stringency index normalized to uncontrolled levels in 1966 was generated[2].

[Figure 3 HERE]

As discussed above, each incremental change in emissions stringency brought new technological innovations in pioneer countries. It is important to note that for most of these newer technologies to work efficiently the quality of fuels used also needs to be improved. For instance, the lead in gasoline poisons catalysts used in CCs, rendering them ineffective. Other measures include octane boosting additives for optimized performance and vapor pressure control to reduce evaporative emissions. To meet higher emissions stringency the sulfur content has to be low. Sulfur in gasoline deposits on the substrate that

houses the catalyst in CCs, thereby reducing its performance and durability. The EU and the U.S. EPA imposed fuel quality regulations simultaneously with emissions regulations. Lead-free gasoline and sulfur content limits are in force.

Most late-adopter countries follow either the European standards, those of the U.S. EPA, or some variation of either. For instance, Korea is proposing its own driving cycles. Driving cycles mimic typical on-road driving patterns to assess fuel-efficiency and emissions of vehicles, which by definition is country-specific. On the other hand, India modified EU cycles to accommodate low-power vehicles like two and three-wheelers. Countries that previously had minimal or no emissions standards are catching up fast. China, for instance, plans to be EU equivalent by 2010 (Homeister, 2001).

China

In China, regulations restricting automobile emissions started with The Law of the PRC on the Prevention and Control of Air Pollution in 1988. The Chinese government revised emissions regulations in 1995, limiting emissions based on ECE norms (CONCAWE, 1997). Then, in 1999, the State Environment Protection Agency (SEPA) set up a three-phase national technical strategy in conformation with EU standards mandating Euro 1 in 2000-01, Euro 2 in 2004-5 and advanced levels by 2010.

India

The Air Pollution Prevention and Control Act of 1981 and the Motor Vehicles Act of 1986 are the basis of automobile emissions regulations in India. Idle emissions regulation was introduced in 1986, but the first stage mass emission norms only came into force for petrol vehicles in 1991. Although India followed the UN-ECE rules, they defined their own driving cycle (CONCAWE, 1997). In April 1995, new mandates required incorporation of CCs in new petrol passenger cars in metro cities along with unleaded petrol (ULP). Euro II equivalent, Bharat Stage II norms came into force in 2001. Since 2005, Euro III norms are in place.

South Korea

The Air Quality Preservation Act under the Environmental Policy Act of 1990 provides the basis for vehicle emission standards presently in force in South Korea. In 1988, government mandated catalytic

converters (CCs) to be incorporated in cars. Since then, South Korea strengthened regulations a number of times; but they still lag behind those of Europe. Gasoline-fuelled motor vehicles became Tier 1 compliant in 2000, and then upgraded to meet Tier 2 by 2002. As of 2006, Euro IV / ULEV are in place (Jeon, 2002).

Thailand

The Enhancement and Conservation of National Environment (ECNE) of 1992 is the basis of environmental controls in Thailand. Thailand first required new vehicles to fit CCs in 1993, when it adopted test-cycles and emissions standards conforming to ECE regulations (Asif et al., 1996). They moved to Euro 1 standards in 1994 and Euro 2 in 2001. In mid-2002, the ECNE was amended to redefine environmental standards and subsequently Euro 3 was adopted in 2004 (CAI website).

(b). Other Policy Measures Influencing the Automobile Industry

To meet the emissions limits mandated by the government, automobile manufacturers have to make changes to the engine technology in vehicles produced. However, the adaptability and modus-operandi of the automobile industry is also affected by the respective industrial policies governing the industry. For instance, the policy towards the automobile industry is laissez-faire in some countries and not so in others. Moreover, government directives on export and import restrictions can also affect access to new emissions technologies that manufacturers in other countries are using. The next paragraphs briefly discuss these augmenting policies in the four countries

China

The Chinese automobile industry was set-up in 1956. However, until the early 1990s the industry produced mainly medium-sized trucks (Bhalla et al., 2002). Now almost every province in China has its own automobile factory. Distorting national policies, however, led the people-per-car ratio to be one of the highest amongst major world economies. Automobile policies initially focused on the national industry becoming self reliant. Therefore, only Provincial governments were allowed to set up production units using Soviet technologies (Gan, 2001). This practice reduced opportunities for healthy competition.

Moreover, most of the factories operating in 1998 were located in far-flung areas, each serving small jurisdictions, making the units economically inefficient (Francois and Spinanger, 2004).

New directives, however, encourage both foreign investments and car ownership. Bank loans are made available at low interest rates to purchase cars giving a boost to market demand. In 1986, new joint venture (JV) laws allowed State Owned Enterprises (SOEs) to sign contracts directly with foreign technology suppliers (Yang, 2000). The Automobile Industry Policy (1994) encouraged foreign technology transfers resulting in SOE-foreign JVs with Volkswagen, Honda, General Motors and Citroen. The "fourth wave" of investments, beginning in 1999, brought investment capital from major Japanese and German companies (Gan, 2001). Subsequent to joining the World Trade Organization (WTO) in 2001, the government gave consent for JV projects to BMW AG and Hyundai (Verband der Automobilindustrie). Nevertheless, government imposed trade restrictions like quotas, high tariffs, and differential taxes that favor local suppliers, are yet to be completely phased out.

India

Various regulations governed the Indian automobile industry since the country became independent in 1947. Initially, the industry was limited to just three players and government severely restricted imports, collaborations and equity ventures until 1991. Technology transfer from foreign companies required government approval. This changed with the adoption of a new automobile policy in June 1993 that removed quotas and deregulated the industry.

This new policy attracted a large number of foreign companies, including General Motors, Ford and several European, Korean and Japanese manufacturers. The industry moved from one restrained by tight government controls to one driven by inherent domestic growth. In 1981, the government set up Maruti Udyog Limited in collaboration with Suzuki Motor Company of Japan and introduced a "people's car" in the economy segment of the market. This led to a boom in demand for automobiles in India. Several large MNCs subsequently entered the Indian market as subsidiaries and joint ventures. Unlike Korea, however, managerial control is shared with international companies. All joint ventures are to manufacture cars and not merely assemble imported completely knocked down (CKD) units. A minimum

foreign equity (Auto Policy India, 2002) of $50 Million U.S. is mandated for a majority foreign-equity ownership, as is the phased indigenization of components. Several assemblers, therefore, have had their own overseas components suppliers enter into joint ventures with local firms. There are presently sixteen players,[3] both Indian and foreign, in the Indian market.

South Korea

The Korean automobile industry started as an export operation in the 1960s. Due to the small domestic market, Korea targeted North America as its primary market. Government policies encouraged exports but kept private transportation as an expensive option at home. Officials at the Ministry of Commerce, Industry and Energy (MOCIE) report that exports today amount to two-thirds of cars manufactured.

Prior to 2000, the car industry was highly protected and subject to controls to shield it from excess competition (Amsden et al., 1995). Hyundai was the only company permitted to manufacture cars up until 1990. Prior to the 1990s, the climate for foreign direct investment (FDI) was characterized by restrictive, mandatory local content requirements. These were abolished in 1995; however, the South Korean industry retained protection from competing with imported cars, also known as completely built-up units (CBUs) in its domestic market (Abrencia, 1998). In 1998, new government initiatives encouraged joint ventures (JV) and mergers and a number of foreign firms entered the fray, although equity control remains with local partners. According to MOCIE officials, in 2000, the French company Renault's merger with Samsung Motors marked the first foreign takeover, with two others following in 2002.

Thailand

In contrast, the Thai automobile industry consists primarily of foreign-owned firms. The Industrial Investment Promotion Act of 1960 lays out incentives for automotive assembly plants to locate in the country. In response, multinationals from the U.S., Japan and Europe set up production units. Since entry was not controlled, production units were unable to achieve economies of scale (Fujita, 2001), with too many automakers catering to a limited market. These units however were highly import-dependent and led to trade deficits. Government resorted to a policy of import-substitution mandating increasing

localization of parts between 1970 and liberalization in 1991. This period saw a number of European and U.S. firms pull out, with Japan gaining major market share. With liberalization, FDI got a boost with most MNCs returning as tariffs were reduced and localization requirements abolished. All automobile assembly units in Thailand are foreign-owned. However, 1st-Tier components[4] manufacturers are foreign joint-ventures with fully Thai-owned manufacturing confined to 2nd-Tier components alone.

In 1993, Thailand also signed free-trade agreements with other nations in the Association of South East Asian Nations (ASEAN)[5]. Subsequently, the Thai government shifted the automobile industry's focus from the home market to promoting exports. This brought new investments from all the major MNCs. Presently, almost all global players, including Korean manufacturers, have a base in Thailand, as this gives them access to the ASEAN market. While the main market in Thailand prior to 1991 was domestic, post-liberalization markets expanded to ASEAN, Japan and some EU countries.

The key differences among the four countries are in the type of manufacturing units, target markets and their trade/FDI policies (Table 2). China and India have a mix of indigenous manufacturers, joint ventures and subsidiaries operating, while Korea had a largely indigenous industry until 2000. Thailand, on the other hand, has largely foreign manufacturers. China and India, with high people-to-car ratios, focus on their domestic market, while Korea's main market is the developed world and Thailand caters to ASEAN. The countries had protectionist policies for varying periods before opening up to foreign competition. Thailand oscillated between openness (1960-70, 1991-present) and import-substitution (1970-91). India, on the other hand, first opened up its automobile market in 1991, followed by South Korea in 1995, and lastly, China joining the WTO in 2001.

[Table 2 HERE]

As hypothesized earlier, I expect the policies discussed above to affect the automobile industry's access to control technologies**,** thereby influencing the ability of a country to adopt stringent regulations. Table 3 includes information from sections (a) and (b) to give a time-line of regulatory revisions vis-à-vis trade and investment policies in each country. Interview data is analyzed below in light of this timeline.

[Table 3 HERE]

V. Analysis

The interview data analyzed below shows regulations in developing countries follow emissions control technologies that are already on the shelf in developed countries. Opening up to foreign investments and trade enables developing country manufacturers to collaborate and access technologies that have been developed in countries that regulated earlier. Requisite technology is procured by indigenous manufacturers through licenses and joint-ventures with foreign manufacturers. This enables regulators in developing countries to adopt more stringent regulations than they otherwise would. Some manufacturers in these countries are using even more sophisticated technologies to meet stricter regulations to break into the export market. The experience gained by manufacturers in meeting export market regulations in turn enable adoption of stricter regulations at home. However, domestic manufacturers need to invest in adaptive R&D to incorporate foreign technologies into their vehicles. Regulators are therefore unwilling to adopt stricter regulations unless the domestic industry as a whole is capable of complying with such regulations. Moreover, more sophisticated technologies need improved fuel qualities to work efficiently. Hence, lack of both adequate in-house R&D and required quality fuels could slow the pace of adoption. Each finding is discussed in detail in the following paragraphs.

Regulations are technology-following rather than technology-forcing

Unlike regulations in advanced countries that forced the development of new technologies, developing countries in Asia adopt regulations that can be met with demonstrated technology. Lessons learnt from the experience of those that regulated earlier make it easier for those that regulate later. Technology experts in Korea and India concur that any policy to regulate the environment is strongly associated with technology (KR5, IN8: Please refer to Table I-1 for interviewee particulars). They therefore look to pioneer country regulations and control strategies for guidance. Technology experts and policy makers in both countries are unanimous on this point. In the words of one technology expert (KR3):

> We study the standard (emissions) history (and) we also study the foreign country's technology.

Policy researchers in India express similar views -

(IN1): We did not have technologies like four-stroke engines for two-wheelers, but we thought, this could be our starting point. We cannot go straightaway to those (higher) stringency levels but (slowly) with EU1, EU2 the gap will be reduced.

(IN3): In Europe, they have gone in a stage-wise manner. We have experience to fall back upon. So in framing regulations, we could easily adapt their regulations to Indian requirements with little effort.

For instance, India's Auto Fuel Policy lays down the emissions control strategy and schedule of regulations with graduated stringency levels for a ten-year period. This strategy is adapted from European standards to fit the Indian transportation scenario. The Indian regulations include emissions limits for two and three wheeler vehicles simulating an Indian drive-cycle. China and Thailand too have followed pioneer country emissions limits for vehicles in their respective countries. In South Korea, regulators say they adopted the U.S. standards for gasoline vehicles and EU standards for diesel vehicles, as these fore-runners have proven strategies in their respective categories. In each category, South Korea chose to follow the lead of the countries with more stringent regulations.

Although pollution levels are on the rise as new vehicles come on the road, none of these countries conducted a conventional cost-benefit analysis to determine what and how much to control. Korean policy advisors (KR4, KR5) say they do not have the tools to measure the harm inflicted by various pollutants. Instead they opted to use international measures as a guideline for regulating cars in South Korea. The UNECE has formulated environmental impact assessment tools that member countries can adopt. Late-adopter countries are therefore introducing fuel quality and emissions standards decoupling environmental impacts from actual transport growth.

The trigger for initial regulations was either a 'crisis' or an external event in three of these countries. In preparation for hosting the Olympic Games in 1987, the Korean government had to meet the approval of the international inspection committee. Improving air-quality was a priority in cleaning up the city of Seoul. The government wanted to portray a 'good national image' (KR3). Korean researchers say they recommended adoption of catalytic converters to be installed in vehicles in Seoul, as this technology was in use abroad (KR3, KR4).

Subsequently, regulatory authorities (KR1) say regulations needed to be further strengthened. With the growth in the number of vehicles, the technologies adopted were not sufficient to contain pollution. In the words of one Korean policy maker:

> (KR1): Even though (our) technologies are getting better, it is not keeping up with the speed in the number of vehicles.

Later, South Korea was selected to host another international event, the FIFA World Cup in 2002. In preparation for such an event, pollution levels had to meet international standards, so regulations had to be strengthened and new technologies adopted.

> (KR4): In 2002, before the World Cup, we had (mandated) the 3-way catalytic converters (for private vehicles) and switched to CNG for public transportation.

A similar motivation guides the Chinese adoption of regulations as well. To get the approval of the international community environmental regulations came to the forefront in China as well. China adopted emissions regulations on the eve of joining the WTO in 2000, and has since rapidly increased stringency requirements in preparation for hosting the 2008 Olympics.

In contrast, India adopted emissions regulations in response to Supreme Court mandates that followed a public litigation case to clear the air in Delhi. The 'crisis' in this case was the 'discoloration' of the Taj Mahal, a national monument. The Court verdict directed the government to relocate polluting industries and curb vehicular emissions[6]. Indian policy advisors say that they did not have an inventory of pollutants or polluting sources to formulate their own regulations. Rather than using cost-benefit analysis to determine an optimal level of regulation for India, regulators opted to adopt minimal requirements prescribed by international norms. Subsequently, researchers say regulations had to be reassessed. As of 2005, India commissioned apportionment studies to determine polluting sources. Later revisions bring new classes of vehicles under the purview of mandates.

Regulators, however, check readiness of the industry to meet mandates. In India, policy-makers (IN3) say every 2-3 years they appraise the efficacy of all steps taken towards meeting mandates. Korean policy-makers say they check with their auto-industry. In the words of one Korean, policy-maker:

(KR1): Before we come up with new regulations, we first talk with the automobile industry. We hear what they have to say.

In both Korea and India, government uses the opinion of experts to direct policy. One technical expert (KR5) says the government has 'open hearings' and they "invite engineers from different (automobile) companies, NGOs sometimes, before chalking out an agenda". In doing so, regulators ensure that regulations adopted can be met with demonstrated technology. Regulators "basically decide on as strong an emission standard" that is possible given technologies already being used in pioneer countries. Both policy and technology experts (KR1, KR5) concur that, "motor companies must be able to meet the standard" with the technology "otherwise it (regulation) will be meaningless."

Chinese law-makers are faced with a similar dilemma. Since both foreign joint-ventures, as well as domestic manufacturers, face the same standards, "the Chinese government is reluctant to pass more aggressive standards" fearing that domestic companies "cannot meet them" and will "go out of business" (Gallagher, 2006, p.388). Such considerations, however, are not the case in Thailand, as all manufacturing units are subsidiaries of MNCs. Multinational companies are capable of meeting standards at home and therefore regulations in Thailand follow close on the heels of Europe.

Opening up the industry to international trade and foreign investments has made technologies accessible and enhanced sharing of concepts

While regulators check readiness of the industry prior to imposing a mandate, it is openness that helps manufacturers acquire technologies to meet these regulations. The roadmaps that regulators chalk out in advance give automobile manufacturers time to collaborate with partners (trade/joint-venture) and source requisite technology to meet mandates. Opening up to foreign markets and investments gives domestic manufacturers access to foreign technologies. Tariffs and investment barriers are relaxed when countries join the WTO, bringing in foreign investments and making foreign technologies more accessible. Manufacturers find that their options have widened and they themselves need not develop all the technologies required to meet mandates. Deregulation of the industry enables domestic firms to collaborate with foreign manufacturers to produce or procure emissions control equipment. Moreover, competition both between and from MNCs actually helps bring technology prices down.

(i) *Openness and Regulation*

In Table 3, we saw that stricter regulations coincide with the opening up of these economies to foreign investments and foreign trade. For instance, although Korea mandated catalytic converters in 1987 prior to the Olympic Games, they adopt stricter regulations only after joining the WTO in 1995. Joining the WTO gives domestic manufacturers access to foreign imports of emission control technologies. We notice yet another revision in 2002 after allowing foreign investments in the industry. India also steps up stringency requirements after opening up their industry to foreign investments in 1994. Chinese regulations accelerate with WTO membership in 2001, requiring a relaxation of trade barriers. Although China's 1994 auto policy encourages technology transfer and foreign investments, most auto-MNCs enter China only in 2000. Chinese emissions regulations strengthen subsequent to this boost in foreign investment. In Thailand, although the automobile industry is comprised entirely of multinational companies, import restrictions were in place between 1970 and 1991. Interestingly, no regulations were imposed during this time. Thailand adopts emissions regulations only after relaxing import restrictions in 1991. This trend suggests that foreign technologies become more accessible when they relax trade and entry barriers, enabling these countries to move to stricter regulations.

Foreign investments in the automobile industry bring in better technologies capable of meeting emissions regulations in their respective home-countries. Gallagher (2004) finds "foreign-Chinese joint-venture firms could easily comply with more stringent regulations through technology-transfer," as "foreign firms continue to innovate to meet stricter standards at home." Such innovations by foreign firms make it easier for the host country governments to impose stricter regulations as well.

Interview data also supports this hypothesis. The impact of joining the WTO and opening their industry to foreign investments is reflected in discussions with policy makers and manufacturers in India and South Korea. Collaborations have become possible after opening up the industry to foreign investments and trade. Allowing foreign investments in the industry not only brought automobile

multinational corporations into the country, it also opened doors to components manufacturers like Siemens and Bosch. Automobile multinationals encourage their components manufacturers to relocate as well. Hence, collaborations are not only forged with joint-venture partners, consulting companies, and foreign research centers, but also with Tier 1 suppliers like Siemens and Bosch. Indian manufacturers say that all the big components manufacturers now have a base in India.

> (IN5): All the major world players are in India as also the components manufacturers (since) duties have gone down subsequent to joining the WTO.

The advent of foreign components and automobile manufacturers has broadened options for domestic manufacturers. Indian manufacturers say it is now easier to meet mandates because "everything (control technologies) is not to be developed (in-house). We can always outsource, we can buy or outsource development of technologies." (IN5)

Manufacturers in Korea say they often collaborate with Tier 1 'global companies' now located in Korea. In the words of one Korean manufacturer:

> (KR7): We can call and ask for prototype(s). Usually they (foreign manufacturers) supply the prototype through (their) headquarter R&D center, e.g. Johnson Matthey is located in England and Engelhard in New Jersey. When the technology is brand new, they supply through their HQ. When it is well-developed,…the local supplier could supply that prototype.

Opening up the industry to foreign investment also increases competition among firms. The Indian government liberalized its markets in 1991. This step had a positive impact on technological development in the automobile industry. Indian automobile companies say prior to 1991, there was hardly any competition and so development of technology also did not take place (IN6). Domestic manufacturers did not have the know-how and neither were companies motivated to innovate. When foreign competitors entered the market, the equation changed. MNCs had the technologies to meet emissions regulations, which put pressure on domestic manufacturers. At the same time the entry of MNCs into the market enabled forming collaborations to enable transfer of technologies.

Manufacturers in both Korea and India say that decisions with regard to collaborations are strategic decisions taken by the individual company. To be competitive, different firms adopt different strategies to lower costs. Maruti Udyog in India, for instance, has a technology transfer division to coordinate technology issues with their joint-venture partner Suzuki of Japan. Often engineers go from India to Japan to research and develop required technologies with their partner. Reducing costs, however, is a priority to meet domestic demand and hence, some research is geared towards 'value-engineering'. In contrast, Korea does a lot of the research 'in-house.' Nevertheless, they do cooperate with foreign countries, often European countries. One Korean technology expert (KR6) says "if it is cheaper to develop then we develop the technologies ourselves. If not, we import it. (The key thing is) reducing production costs". Korean manufacturers need not replicate research done by components manufacturers for instance. Instead, they source these from foreign components manufacturers. Since multinational components manufacturers (Tier 1 companies) are global players they do substantial research themselves. One Korean manufacturer says:

> (KR7): Bosch has a number of very important patents, its one of the biggest. They invest a lot of money to develop these technologies and they mass produce this technology. These companies have experience working with and supplying to Toyota and Ford. So all we need is the component (from them) to jump to newer standards.

Such technologies are expensive. Prices, however, are coming down, both as a result of trade barriers and tariffs being lifted, as well as increased competition among components manufacturers. Moreover, technologies get better and cheaper with time making it easier for late adopters to employ them. For instance, catalytic converter technology has improved both in performance and durability since they were first introduced in the U.S. Initially when these technologies were introduced in the U.S. market prices were high. Components made by various multinational companies "are similar in terms of performance and durability (KR1)". Korean car-manufacturers usually get different suppliers to compete to supply components. One manufacturer (KR6) says, components suppliers "compete and we look at both cost and performance of the equipment". Manufacturers say that it takes just two or three years for other components manufacturers like Siemens and Delphi to catch up with what Bosch makes (KR7). With this kind of competition prices come down quickly. This partially explains the time-lag between adoption of

regulations in the EU and countries in Asia. Domestic automobile manufacturers now have alternatives and make decisions based on price. If it is cheaper to develop technologies in-house they do so, if not, they outsource. With an increase in the number of Tier 1 companies entering developing country markets, the price of emissions control equipment is falling.

(ii)The Export Market and Regulation

The export market is also seen to indirectly drive regulations at home. The export market acts as an incentive motivating manufacturers to achieve higher standards. As the industry gears itself to meet the demands of their major export markets, having parallel standards at home makes economic sense. This is seen in the case of South Korea. Two-thirds of Korean automobiles are exported to advanced countries like the U.S. South Korean regulations for gasoline vehicles therefore follow those in the U.S. For diesel vehicles, they follow EU standards as their main market is Europe. Policy makers appreciate that having different standards at home would mean that auto-manufacturers will have to develop different engines for the two markets. They therefore mindful of this while formulating policies at home. In the words of one policy-maker:

> (KR1): If we use different standards at home than that in the US the automotive company has to develop different types of engines. In order to reduce the burden of companies we have standards that are like (similar to) US standards for gasoline vehicles and European standards for diesel vehicles. The main focus is to keep a balance between tightening regulations for the environment and for the industry- to prop up our industry.

The main market for Korean manufacturers is the U.S. Market. Since the U.S. has stricter regulations, Korean car manufacturers incorporate sophisticated emissions control technologies to meet US requirements. One policy advisor says:

> (KR6): We buy the catalyst (catalytic converter) from foreign countries, but we can not just put the catalyst in a normal car. We have to enhance the performance of the car to put the catalyst in (so) that it can function as it is supposed to. So that's the job of the Korean industry- to enhance the performance and make the catalyst work.

Technology experts in Korea say:

> (KR5): if we have different emissions standards at home then the companies have to develop different engines. So the meaning of numbers here is very sensitive, how much CO, HC, etc to reduce. They have to calibrate the engine to meet these numbers.

Other interviews agree. According to a Korean regulator:

> (KR2): If South Korea modernizes its standards to international levels then manufacturers can make cars according to just one international standard and reduce production costs. That can act as an advantage for the automobile industry. Although there is only one production line, cars for different markets have to be managed differently in the line.

A similar experience is observed in Thailand as well. Subsequent to signing free trade agreements (FTAs) with the Association of South East Asian Nations (ASEAN), automobile exports from Thailand to South East Asian countries got a boost in 1993. Most of such exports were to countries within Asia with higher regulatory requirements like Singapore and Hong Kong. Foreign manufacturers based in Thailand would find it easier to manufacture similar products for the market in Thailand as for the export market. We see that regulations do get stricter in response to the export market regulatory needs in 1995 and 2001 with revisions in standards in Singapore and Hong Kong (refer Figure I-3).

In contrast, both China and India have a mixed type of industry where JVs co-exist with indigenous manufacturers primarily catering to the domestic market. Yet, some manufacturers in these two countries are also acquiring technologies to meet export market standards. A few Indian firms have expanded their markets and now export cars to Europe. One Indian manufacturer (IN5) says, "We have the multi-point fuel injection (MPFI) system, which we are using for those vehicles (in Europe)." More recently, the Landwind Fashion of China made an entry into Europe (Tagliabue, 2007). Manufacturers that export cars have the technologies to meet higher standards.

Nevertheless, the main market in both these countries is domestic and they have a number of domestic firms in the industry. Most firms are therefore focused on domestic market needs. If regulators adopt more stringent regulations every manufacturer will have to meet the same standards. Unless all

domestic firms are up-to-speed, this could pose a problem. Regulators in these countries therefore refrain from imposing stricter regulations that could harm the domestic industry.

Mismatches in absorptive capacity and related industry infrastructure could slow down adoption of more stringent regulations

As discussed above, developed country technologies could play an important role in motivating developing countries to adopt regulations quicker than they otherwise would. However, two factors could act as stumbling blocks. First, individual companies must do their own research to incorporate advanced emission control technologies into different makes and models. Second, for emission control technologies to work efficiently the quality of fuels used must also improve.

When emissions control technologies are adopted, there are two types of technological innovations involved. One is the 'after-treatment component', which is supplied by Tier1 parts suppliers and not manufactured by the automobile manufacturer or Original Equipment Manufacturer (OEM)[7]. For instance, Ford could use a catalytic converter (CC) made by Bosch in their vehicles. However, to incorporate the CC, Ford has to make necessary changes in the engine controller. Therefore, to incorporate these devices into different makes and models the OEMs have to make adaptations to their engines. This is where automobile manufacturers have to invest in research and development. Korean manufacturers say "the controller has to be fine-tuned (and) how one controls the operation of the catalyst is very important" (KR5). Manufacturers both in India and Korea say that such fine-tuning is done by individual OEMs and is privy to the company (KR7, IN5). In India, industry experts are concerned that although domestic manufacturers have some R&D this may not be enough. They say, although there is sharing of concepts, manufacturers in India do not share technologies (IN4). Unless all domestic firms in the industry increase research and development efforts, adoption of regulations will be slow.

On the other hand, the automobile industry is export-focused in South Korea. The export sector is a priority sector and hence, the Korean government plays an active role in technology development. The

government sponsors a number of projects to promote technology development in institutes like the Korean Institute of Machinery and Materials (KIMM). If there is any need for a new technology, "it is the government who forms a team on a project and funds it. This is then available for all parts companies to produce (KR2)." Yet, stricter standards cannot be met with after-treatment devices alone. Technology experts claim:

(KR 5): (Manufacturers) use (d) the same mother engine to meet newer standards. They do this by putting stronger after-treatment techniques. However, they cannot meet all emissions standards with catalyst technology. They have to develop new engines.

Domestic R&D, therefore, is a crucial factor in enabling industry to comply with stricter standards. Experts in China concur that "indigenous innovation" is required for the Chinese "industry to develop efficiently and effectively (Raja, 2007: quoting Hu Shuhua)." In contrast, Thailand may not need domestic R&D since manufacturers are essentially multinational corporations with experience in their respective home country markets.

Then again, the lack of availability of required quality of fuels can delay adoption of stricter regulations. In India, manufacturers have the technology needed to meet regulations in export markets (IN5, IN7). Yet, India cannot introduce the same regulations at home because the necessary fuels are unavailable (IN3). For instance, to meet Euro 2 regulations the technologies adopted require lead free gasoline to work effectively. Automobile manufacturers had bilateral discussions with oil companies to coordinate introduction of newer technologies. The transitioning however has not been smooth (IN4) and fraught with delays. For instance:

IN 4: Euro II was to be introduced all over the country from April 1st, 2005, however, the day before, that is March 31st, 2005, Ministry of Petroleum and Natural Gas (MOPNG) announces that they do not have the fuel quality available across the country, and it will be delayed by a couple of months in 7 states. So Ministry of Road Transport (MORT) had to issue fresh orders to postpone effective dates. This affected the auto-industry as they could not change the production line.

Lead has subsequently been phased out of fuels in all four countries and refineries had to make adjustments, incurring costs. Lead, however, is not a component of crude oil and is only added to increase

octane levels[8]. Therefore, all refineries had to do was use alternative (expensive) octane-boosters. This, however, is not the case with sulfur. Sulfur in gasoline clings to the substrate that houses the catalysts in catalytic converters rendering them ineffective. To move on to restrictor emissions limits like Euro 3, the sulfur content in gasoline needs to be considerably reduced. Desulphurization equipment is expensive and prohibitive for most refineries. New equipment and huge investments are needed. Lack of adequate and parallel investment in the refining sector can impede adoption of more stringent regulations.

Unlike the automobile industry, petroleum refining is a public sector undertaking (PSU) in countries like India and so foreign investments are not permitted. Of the nineteen refineries, only two are private and capable of meeting stricter standards. Both the private undertakings are newer ventures in collaboration with foreign companies. Reliance Group refinery is a joint-venture with Bechtel Corporation of the U.S. A majority of these refineries are however public sector undertakings, including Indian Oil Corporation (11 refineries), Bharat Petroleum (BCPL) and Oil and Natural Gas Company (ONGC). First, these are older refineries, most built in the 60s and early 70s. This has impeded the ability of the petroleum refining sector to meet fuel quality requirements. Moreover, unlike the automobile industry where some firms are gearing to meet stricter regulations in the export market, refineries are not. They, therefore, are not competing to meet international standards. In the words one policy expert:

> (IN3): To meet Euro IV norms, major structural changes will be required for oil companies, and vehicle manufacturers as well will have to augment their service centers. The auto industry is private and they are internationally more competitive. They have found that if they progress to higher standards their exposure to the international market will be much more. (Whereas) there are just 2-3 private refineries and hence, investments for companies like OIL and BCPL was phenomenal to meet the requisite fuel standards.

China, too, faces a similar dilemma. It has its own off and on-shore oil reserves and primarily refining is done by the China Petroleum and Chemical Corporation (Sinopec) a public sector undertaking. In 1995, two of its 27 refineries joined hands with MNCs in Saudi Arabia (Aramco) and the U.S. (ExxonMobil). Studies (Walsh, 2003), for instance, find that China does not have the refining capacity to

meet sulfur content limits for tighter emissions restrictions, and this could hamper a move to stricter regulations.

In contrast, Thailand and South Korea have opened their refineries to the private sector. In Thailand, refineries have been privatized since the financial crisis in 1997 and multinational companies are now in control (Lovei, 2003). These companies have the know-how to meet standards in their home countries. The refinery sector is therefore better able to meet requirements. Although South Korea imports its crude oil, it also exports refined gasoline. Refineries in South Korea are run by multinationals like GS-Caltex and Chevron who have the equipment and the know-how to reduce sulfur from crude. Both these countries have therefore been able to meet fuel-quality requirements and adopt stricter regulations at home as well.

The experiences in these countries show that regulators have been able to impose stricter standards in countries which allow foreign investments. Nevertheless, if absorptive capacity in terms of domestic R&D and required fuel quality do not match up in these countries, further tightening of emissions regulations will not be feasible.

VI. Conclusion:

In contrast to studies that focus on factors driving the demand for a better environment, this study looks at factors that enable less developed countries to regulate for the environment. Diffusion of technologies developed in countries that pioneer emissions control regulations help other countries adopt similar regulations. Late adopters benefit not only from the research done by manufacturers in countries that adopt regulations earlier, they are also able to avoid mistakes that some such countries made.

Contrary to conventional practices, regulators in these countries do not formally weigh the costs and benefits of imposing regulations. Constrained both by computational capacities and uncertainties of the inventive process, they instead adopt a kind of rational behavior that is compatible in the context.

Regulators look to regulations and technologies already in use in advanced countries, to guide regulations at home. Interview data reveals that developing countries in Asia prefer to adopt regulations that can be met with proven technologies. Opening up their economies to foreign investments and trade enables the flow of foreign technologies and exchange of ideas to curb pollution. Collaborations and competition between multinational components manufacturers has helped bring prices down, making technologies both affordable and accessible. Foreign technologies and collaborations thus enable these countries to adopt regulations faster than they otherwise would.

Foreign emission control technologies, however, need to be adapted before being incorporated into different vehicles. Developing countries, therefore, have to incur costs to use these technologies. For technologies to work efficiently, countries must also modify infrastructure in related industries like oil refineries. This in itself is a huge cost. For countries that have privatized the petroleum sector and allowed foreign investments, the transitioning to stricter standards has been easier. Foreign technologies and investments in the petroleum sector, as with the automobile sector, enable refineries to meet stricter regulations as well. A mismatch in the development of related sectors, like the petroleum sector in this case, is a bigger impediment than technology availability in moving towards stronger regulations.

Foreign technologies do play an important role in enabling developing countries contain pollution. Yet, the wisdom of moving too fast too soon should also be taken into consideration. Caution should especially be employed before rushing and locking into technologies that may soon become obsolete as fossil fuel resources deplete. Such a 'lock-in' could stem the development of alternative engines like the electric engine or fuel cells (Cowan and Hulten, 1996). Alternative fuel use, as in Brazil for instance, could well accord a sounder path for later adopters to follow. In countries where the fuel-distribution infrastructure is not as well developed, considering a portfolio of alternative fuels can be explored.

Figure 1 Growth and Regulations

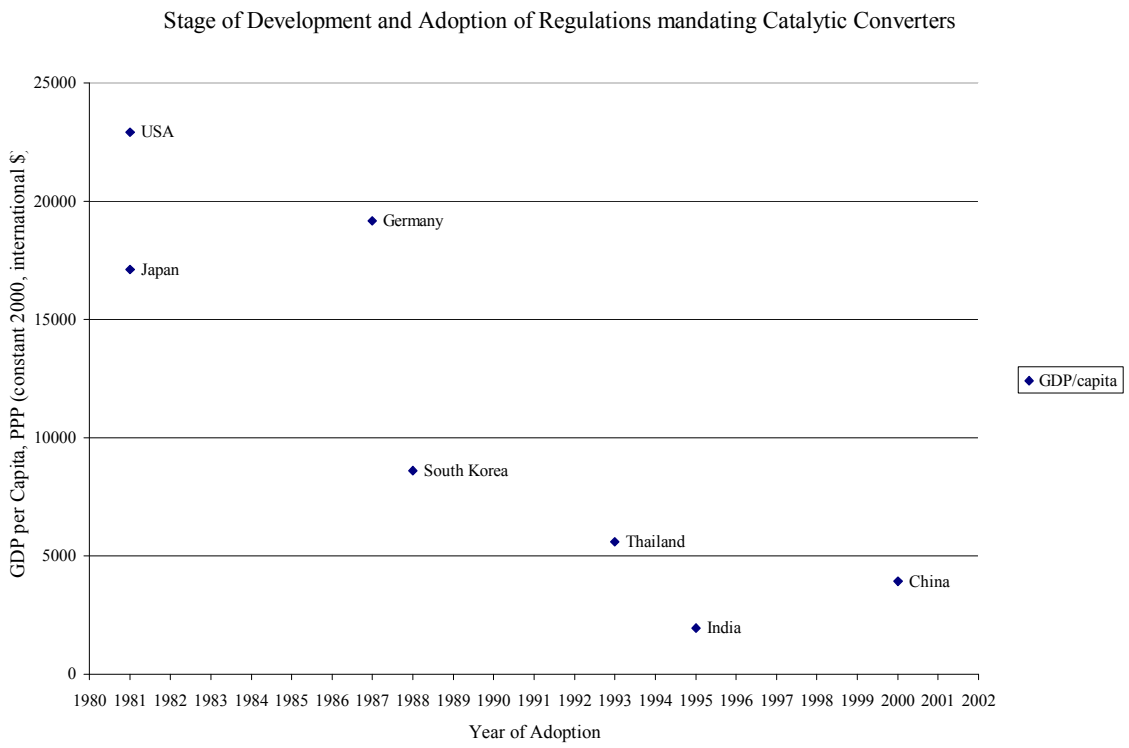


Figure 1 above shows the developmental stage in terms of per capita GDP (Y-axis) of the country at the time period (X-axis) when they first adopted regulations requiring Catalytic Converter technology to meet emissions regulations. The countries on the left are pioneer countries and those to the right are late-adopters. Late-adopters adopt technologies at an earlier stage of development than the pioneers did.

Figure 2 Theoretical Framework

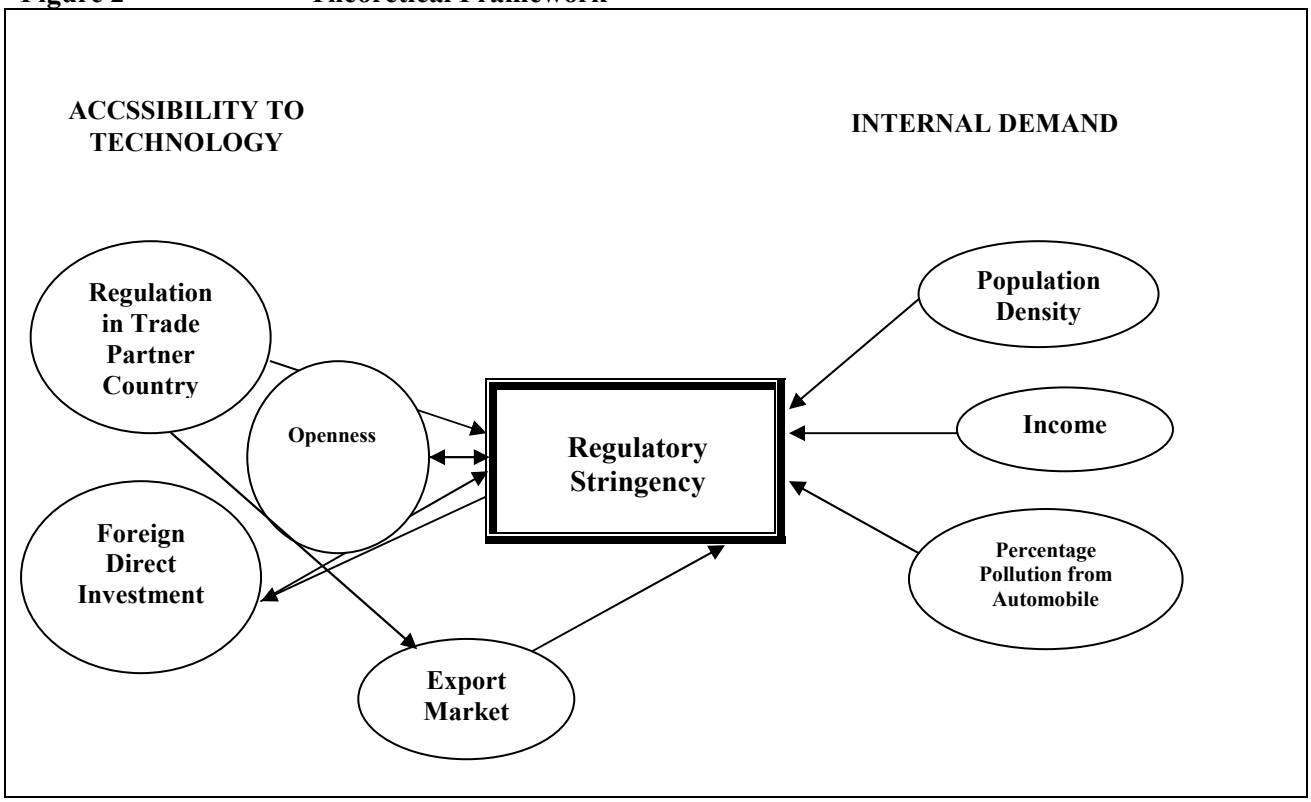
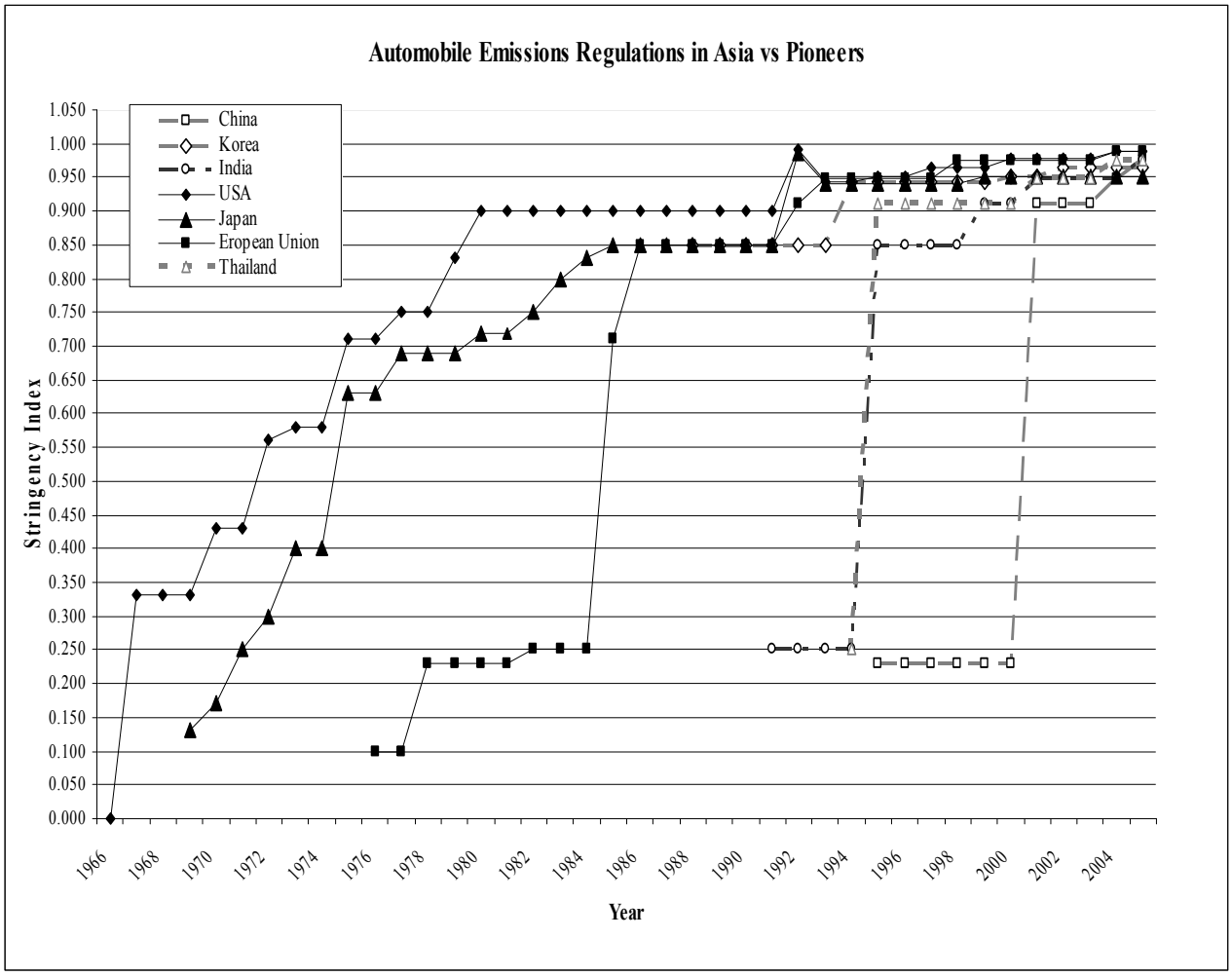


Figure 2 represents the theoretical framework, depicting factors that influence a country's decision to adopt emissions regulations. The factors on the right hand side are conventionally accepted as the driving demand for a cleaner environment. The factors on the left are expected to make foreign technologies more accessible and are the focus of attention in this study.

Figure 3: Progression of Emissions Norms for US, Japan, the EU and Asia



Note: Trends in pioneer countries in bold lines and filled shapes, while for Asian countries trend lines are dashed with outline shapes.

Figure 3 above shows the progression of regulatory stringency in both pioneer and late-adopter (dashed lines and outline shapes) countries. To enable comparison between the U.S., Japanese and EU standards, a stringency index has been normalized to uncontrolled levels of emissions from cars in 1966. While the US and Japan adopt several incremental levels of emissions control to regulate automobile emissions, Germany and other countries in the European Union make a leap in 1986 to catch up. Countries in Asia adopt another decade later in the late 1990s.

Table 1 Interviewee Profile

Code	*Country*	*Agency*	*Category*	*Position in agency*	*Number of years in the field*	**Gender**
KR1	Korea	Ministry of Environment (MOE)	Regulator	Mid-level	7 years	Male
KR2	Korea	Ministry of Commerce Energy and Industry (MOCIE)	Regulator	Mid-level	8 years	Male
KR3	Korea	Korean Environmental Institute (KEI)	Advisor to regulator (Tech)	Senior Researcher	13 years	Female
KR4	Korea	Korean Environmental Institute (KEI)	Advisor to regulator (EP)	Senior Researcher	15 years	Male
KR5	Korea	Korean Institute of Machinery and Materials (KIMM)	Government aided research institute (specific project LEV)	High-level Technical Expert	12 years	Male
KR6	Korea	National Institute of Environmental Research (NIER)	Government aided research institute	Mid-level researcher	6 years	Male
KR7	Korea	Automobile Manufacturer (Indigenous) Hyundai	Regulated	High-level technical personnel	13 years	Male
IN1	India	Ministry of Environment (Federal)	Regulator	Mid-level	9 years	Male
IN2	India	Ministry of Transport (Federal)	Regulator	Mid-level	12 years	Male
IN3	India	Environmental Cell (State Level)	Advisor to regulator	Senior Researcher/ Technical Expert	15 years	Female
IN4	India	Society of Automobile Manufacturers (SIAM)	Regulated	Mid-level management	6 years	Male
IN5	India	Major Automobile Manufacturer (Joint Venture) Maruti	Regulated	Senior Technical Expert (procurement cell)	16 years	Male
IN6	India	Directorate of Transport (Delhi)	Regulator	Senior Administrator	7.5 years	Male
IN7	India	Department of Transport , Implementation Cell (Delhi)	Regulator	Mid-level	8 years	Male
IN8	India	Automotive Research Association of India (ARAI)	Research and testing	Senior Technical expert	18 years	Male
IN9	India	National Automobile Testing and R&D Infrastructure Projects (NATRIP)	Research in technology	Senior Management	9 years	Male

Note: In the case of IN8 and IN9, selective questions pertaining to their area of expertise were alone discussed. Besides in India, talks were also held with experts at The Energy Resources Institute (TERI is a non-profit organization involved in research on environment, energy, policy, technology development and bio-technology).

Table 2 Key variations between countries under study

Country	Industry Characteristics			Augmenting Policies		
	Type	**Market**	**Imports**	**FDI**	**IPR Strength**	**Absorptive Capacity**
Korea	Domestic	Export, Developed	Restricted until 1995	2002	Strong	High
India	Mixed	Domestic	Restricted until 1991	1994	Weak	Low
China	Mixed	Domestic	Restricted until 2001	2001	Very Weak	Low
Thailand	Foreign	Export, Asia	Restricted 1970-1991	1960	Weak	Medium

Table 2 above shows the key variations in policies, market structure and absorptive capacity in the four countries under study.

Note: The IPR data is based on the Ginarte and Park index and the WDI, Rule of Law composite index. Rule of Law is a composite index including business risk, financial ethics, business enterprise environment etc. Korea is ranked in the 78th percentile, while India and Thailand are in the 60th and China is in the 40th percentile, respectively.

Table 3 Timeline of Automobile Emissions Regulation in Asia vis-à-vis Openness

Year	*Korea*	*India*	*China*	*Thailand*
1986		Idle Emission Regulation based on ECE regulations		CLOSED TO IMPORTS in AUTOMOBILES
Up to 1987	Based on Japanese Test Cycle			
1988	Catalytic Converters introduced			
1991		ECE-15/04 **MARKET LIBERALIZATION**		**REOPENS to FDI and Imports**
1993				Catalytic Converters introduced **SIGN FTA s with ASEAN COUNTRIES**
1994	Euro I / US Tier 0	**FDI IN AUTO-INDUSTRY**		Export country regulation revised[2]
1995	**JOINS WTO**	2-way Catalytic Converters **JOINS WTO**	ECE-15/03 **AUTO POLICY TARGETTING FDI**	**JOINS WTO** Euro I
1996		Tightening limits (CO, HC, NOX): Evaporative and Crank Case Emissions		
1998		3-way Catalytic Converters		
1999	**SURGE IN EXPORTS TO DEVELOPED COUNTRIES**	Euro I		
2000	US Tier 1 / Euro II		**JOINS WTO**	
2001		Euro II	Euro I **SPURT IN FDI**	Euro II (Export country regulation revised)
2002	Euro III **PERMITS FDI IN AUTO-INDUSTRY; OLYMPICS GAMES IN SEOUL**			
2004			Euro II	Euro III
2005		Euro III	Euro III	
2006	Euro IV			

Source: Regulatory changes compiled from Faiz, Asif et al, 1996, CONCAWE Report No. 6/97 and the CAI website.

[2] Note: Thailand's export market Singapore revises regulations to Euro I in 1994 and Euro II in 2001; Hong Kong revises in 1995, 1997 and 2001.

Endnote Notes

[1] The exception is Germany, which had stricter regulations even before joining the EU.

[2] To generate the index, I use permissible level of different pollutants as a measure of stringency. Emissions are normalized to the uncontrolled levels of NOx, PM_{10}, CO and, HC that were recorded from cars in 1966 in the United States. Information on permissible levels as well historical levels in 1966 was obtained from Homeister (2001).

[3] Maruti Udyog, Hyundai Motors, Tata Motors, Honda-Siel, Ford India, General Motors India, Hindustan-Motors, Mahindra & Mahindra, Skoda (Volkswagen), Toyota, Fiat, Premier, Daimler-Chrysler, Mercedes-Benz, Premier and Mitsubishi.

[4] 1st-Tier components are engine-parts, electrical-parts, transmission and steering, brakes and body parts, while 2nd-Tier deal with accessories not in base engine and safety parts.

[5]ASEAN – members are Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam

[6] M.C. Mehta versus the Government of India, New Delhi, Ibid 4 SCC 351 and 750, 1985

[7] OEM is used to refer to the company that acquires a product or component and reuses or incorporates it into a new product with its own brand name.

[8] Octane is a characteristic of fuel components that improves the performance of engines by preventing fuel from combusting prematurely in the engine.

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