DRIVING SUSTAINABLE PASSENGER CAR SYSTEMS: THE ROLE OF NATIONAL GOVERNMENT IN ENVIRONMENTAL INNOVATION AND DIFFUSION

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ABSTRACT

Environmental innovation, a key solution to combat climate change, often requires deliberate government efforts. Drawn from various theories, the paper presents a framework of factors that are critical for effective innovation policy design. Looking at historic events around passenger car innovation in the United States and Japan, the paper attempts to test these theory-driven factors in practical settings. It also includes some lessons learned. In addition to the substantial design factors such as vision setting, a proper mix and implementation timing of policy measures, coherence within internal government administration, and consistent policy execution, the author recognizes the importance to understand the contextual background, in particularly including actor-specific characteristics. A contextual background analysis will facilitate better policy and governance design.

KEY WORDS:
Environmental innovation; Policy design; Government role; Contextual and actor analysis; Climate change.

INTRODUCTION

In the past decades, automobile industry showed a remarkable growth rate of over 30%, accounting its global turnover equivalent to the sixth largest economy in the world (OICA, 2007). In 2007, the Industry produced over 73 millions units worldwide and passenger car production alone accounts for over 53 millions units (OICA, 2007). Transportation sector consumes approximately 60 per cent of petroleum products globally and produces approximately one sixth of anthropogenic carbon dioxide emissions (Greene and Wegener, 1997). Within transport sector, road vehicles account for more than 75 percent of petroleum use (OICA, 2007). In the case of US, passenger vehicles account for approximately 40 percent of all U.S. oil consumption, contributing about 20 percent of all U.S. carbon dioxide emissions (USEPA, 2004).

As car ownership is constantly increasing and automobile dependency dominates our mobility, a passenger car system that is heavily dependent on fossil fuel has been a critical area of climate change concern. While continuing our efforts to create more environmentally sustainable mobility, still it is important to revolutionize a current car system with less dependent to fossil fuels. Environmental product innovation, such as energy efficient cars and alternative fuel cars, thus, became an essential component to drive sustainability in current vehicle markets. Fuel efficient and alternative fuel-powered car innovations have appeared for quite sometimes but mainly within testing and/or niche markets. However, the paradigm has changed since the commercial success of Toyota’s hybrid car. The success was significant enough to shake mainstream markets. Other major car manufacturers brought up hybrid car models and accelerated research and development (R&D) on new generation cars including improved versions of electric cars, hydrogen cars, and others. Also many governments restarted their support on sustainable car innovation. As the change became visible, it is difficult not to acknowledge Toyota’s hybrid success to push sustainability in global passenger car systems.

Achieving environmental innovation and diffusion has its own challenges and hurdles. It requires tremendous efforts not only from innovator’s perspective, but also needs institutional support and modality change. A wide range of variables affect the dynamics of institutional change. Many empirical studies on innovation and diffusion show that government and policy supports are ones of the important factors in many successful cases, even though it is also true such deliberate policy support cannot automatically guarantee the success.

The paper aims to discuss how a national government could play a role to accelerate environmental innovation and diffusion so that sustainability system change can occur more effectively and efficiently. More specifically, the paper aims to identify determinant factors in effective policy and governance design that drive the success of environmental innovation and diffusion. It also attempts to validate these factors by analyzing historic events around environmental passenger car innovations in US and Japan. The author, standing on so-called ‘critical realism’ position, investigates some actual pieces of the reality (truth) in depth and uses some degree of probability to understand the reality: what makes governance for innovation and diffusion more successful.
1. THEORETICAL REVIEW

1.1. From Innovation to System Change

The advocates of innovation and system change theory focus on understanding how innovation (whether it is perceived as a new idea, practice, or object) interacts with core components of an existing system, penetrates into mainstream markets, and starts shaking the stable market regime (Hofman, P., 2005). Not every single innovation is validated in a market. Once it survives, it creates a niche market, fulfilling a gap that is created from the problems of existing mainstream market. Possibly, a niche market may represent a picture of future market (Hofman, P., 2005).

Once the niche market gains a certain level of market share, it starts competing with mainstream markets. A broader networks of actors would be formulated and new market trend would be created, start shaking the existing market regime. It would even trigger others to innovate. The conglomerated efforts would create greater driving forces to transform or replace the existing regime. As a result, a system change would occur (Hofman, P., 2005). Highlighting a critical role of innovation for a system change, Schumpeter mentioned that innovation is ‘a historic and irreversible change in the way of doing things’ and ‘creative destruction’ (Schumpeter, J., 1950).

Socio-technical landscape theory elaborates the process of system change. Describing three levels of niche (micro-), existing regime (meso-), and socio-technical landscape (macro-), socio-technical landscape theory elaborates innovation and system change processes. An existing market regime provides certain conditions that may not fulfill a need of some groups of people. Responding to such a gap in the existing market regime, innovation occurs and creates a niche. In other word, innovation in a niche is greatly influenced by the existing market regime and regime institutions. The theory also argues that the macro level of socio-technical landscape such as mega trends, mega-value, mega-shocks, mega-structures, and others influences not only the regime but also the emergence of innovation (Tukker, A. and Butter, M., 2007; Genus, A. and Coles, A., 2008; Nykvist, B. and Whitmarsh, L., 2008).

For instance, oil crises and climate change trigger others to innovate. The conglomerated efforts would create greater driving forces to transform or replace the existing regime. As a result, a system change would occur (Hofman, P., 2005). Highlighting a critical role of innovation for a system change, Schumpeter mentioned that innovation is ‘a historic and irreversible change in the way of doing things’ and ‘creative destruction’. Schumpeter, J., (1950).

1.2. The role of Government and Public Policy to Advance Innovation and Diffusion

Since the mid twentieth century, the history of technology innovation reveals that policy intervention has greatly shaped technology innovation and development by acting as catalysts, promoters, and regulators of innovation-related activities (Meeus, M.T.H. and Edquist, C., 2006). Here, the author likes to focus on the role of government and public policy that are deliberately designed to advance the process of innovation and diffusion. Even though technology innovation and its transition to sustainable system change cannot be under total control but can be absolutely influenced both in terms of direction and speed of the progress (Kemp, R. and Rotmans, J., 2004). Institutional change is an element of transition and public policy can facilitate processes of institutionalization (Kemp, R. and Rotmans, J., 2004; Hofman, P., 2005). As a number of empirical studies proves, public policy and their effects are critical regime and landscape pressure that drives innovation and further shapes system change (Nykvist, B. and Whitmarsh, L., 2008). Favorable policy systems support networks of actors, not only potential innovators but also all regime actors, to respond to sustainability pressure and exploit new opportunities and markets.

In the early phase of innovation and technology policy studies, the basic linear policy model was dominating (Soete, L. and Arundel, A., 1995; Åhman, M., 2006). The basic linear model was developed reflecting typical sequential stages of industry innovation projects. Since the late 1940s, a range of mission-oriented projects/programs were supported by government, mostly linking to the basic linear policy model. The basic linear model suggests that the increase of upstream input flows will directly affect the outflow, marketable products and process. Therefore, policy measures were mainly directed to support both basic and applied research (Soete, L. and Arundel, A., 1995). The linear policy model evolved slowly from the 60s and mostly in the 70s (Åhman, M., 2006), resulting in the emergence of various versions of linear policy model with recognition of the importance of demand-side pull (Soete, L. and Arundel, A., 1995). The sequential linear model, for instance, puts equal importance on different sequential stages of innovation and diffusion processes. It also recognizes possible bottleneck phenomena between the stages. Thus, the sequential policy linear model contains three major types of policy measures. For example it includes: subsidies to improve basic research; competition policy and others to prevent bottleneck possibility in the stage of applied research, and market experimentation; and policy to create demand-pull and innovation diffusion (Åhman, M., 2006).

As globalization pushes increasing competition among nations, serious concern was laid on how to improve the competitiveness of nations, which led to evaluation of innovation policy and its effects. A number of empirical researches in the 80s argued that the linear policy models that are based on stage model of innovation (Forrest, J.E., 1991) failed to support complex process of technology innovation and diffusion (Soete, L. and Arundel, A., 1995). Many researchers recognized the complexity of dynamic interaction occurring in innovation and diffusion process and tried to explain such complex process by developing various models: conversion model, technology-push/market-pull
model, interactive model, integrative model, and others (Forrest, J.E., 1991). Commonality of these models is the emphasis on ‘inter-linkages, interdependency, and interaction’ of various stages of innovation and diffusion.

Soete, L. and Arundel, A., (1995) argued the importance of a ‘system approach’. Their ‘system model of innovation’ has the following characteristics: multi-directional linkages, knowledge and learning, unique development paths, and cumulative effects of the technical change process. Consequently, innovation policy needs to be designed accordingly, moving away from linear policy models and assisting to strengthen technical change process as a whole (Åhman, M., 2006). System characteristics of complex innovation process requires an appropriate policy support: policies to ensure suitable institutional infrastructures so that actor networks to be opened to new ideas and influences; policies to support knowledge and learning throughout innovation and diffusion processes; a right mix of policy measures that can support technology- and sector-specific innovations; more focused policy but flexible enough to adjust changing circumstances; and policies to constantly promote the diversity of new ideas and further innovations. In particular relevance to environmental technology and innovation, Soete, L. and Arundel, A., (1995) add the emphasis on the diffusion of results as a part of innovation policy goals and also on ensuring ‘coherence’ with other policy goals. Similarly, Åhman, M. (2006) highlights the benefits of a dynamic and interactive policy model and argues that various policy measures like R&D; and market and systems of provision supports should be simultaneously introduced for better outcome generation.

A group of Dutch scholars has had a particular interest to explore more focused and deliberate policy efforts for innovation and system change, which is called, ‘transition management policy’. Transition policy aims to investigate the role of the state and public policies that are explicitly designed to induce innovation and to manage transition towards system change. Advocates recognize the high complexity and uncertainty in innovation and diffusion process but believe that public intervention at right point and time could influence innovation direction (Kemp et. al., 2001; Geels, F.W., 2002).

Transition policy intends to influence socio-technical system change by a set of ‘coherent’ policy measures (Kern, F. and Smith, A., 2008). The general strategy of transition policy is to pressure the existing regime by various policy measures, while providing alternative choices (Elzen, B. et al., 2004). Transition policy differentiates niche- and regime-level strategies and policy measures (Elzen, B. et al., 2004; Kemp, R. and Rotmans, J., 2004). Transition policy model tries to tackle persistent structural problems of the existing unsustainable system, which were not able to be resolved by traditional short-term policy (Loorbach, D.A., 2007; Kern, F. and Smith, A., 2008). Therefore, transition policy emphasizes the importance of ‘vision’ as a necessary component of transition policy, which can guide possible and likely pathways for future sustainable system and set clear long-term goals. Taking into consideration plausible technology, markets, and user preferences, a vision should be set based on consensus made by participating front runners.

Transition policy emphasizes the function of so-called ‘transition arena’ (Kern, F. and Smith, A., 2008). The transition arena is where selected members of frontrunners and visionary actors from public and private networks of actors, possibly including powerful and influential players of the system, collectively set a vision and an aligned set of strategies and measures to execute innovation and market diffusion. In that sense, there is a clear difference between a transition arena and a policy network that modern policy theory and governance theory are referring to. Steps (or cycle) of transition policy process can be summarized as follows: formulating transition arena with a visionary multi-actor network; developing sustainability visions; exploring transition pathways through experimenting with specific measures; and evaluating, learning and monitoring the progress (Kemp, R. and Rotmans, J., 2004; Van de Kerkhof, M. and Wieczorek, A.J., 2005). A policy model adopted in this transition arena would focus on learning and coordination phases of innovation, restructuring incentives and constraints (Kemp, R. et al., 1998). Such deliberation would create a better chance to overcome system lock-in and further drive structure change for sustainable system (Kemp, R. et al., 1998; Kemp, R. et al. 2001; Elzen, B. et al., 2004; Kern, F. and Smith, A., 2008). Another important component of transition management model is to maintain ‘substantial policy stability and resilient coalitions’ in order to prevent from derailing transition process (Meadowcroft, J., 2005; Kern, F. and Smith, A., 2008).

As some empirical studies on transition management (or similarly, strategic niche management) reveal, however, this model of deliberated policy does not guarantee success. Rotmans, J. (2005) mentioned that experimental transition management contains both a high risk of failure and potential (Rotmans, J., 2005). Thus, ‘learning’ in the process of induced change through experimentation is an essential part of transition management (Kemp, R. and Rotmans, J., 2004; Van de Kerkhof, M. and Wieczorek, A.J., 2005). Regardless whatever outcomes would be, transition policy is designed to put pressure on an existing unsustainable regime and to provide a level playing field to novelty so to compete with existing ones, rather than deliberately picking winners (Kemp, R. and Rotmans, J., 2004; Kern, F. and Smith, A., 2008). The difference of transition management from strategic planning and control policy is more ‘reflexive and open-ended’ strategy of transition policy (Hoogma et al., 2002). Thus, transition policy is ‘modulation policy’: it is forward-looking and tries to utilize the winds of change, and to seek to exploit windows of opportunity (Hoogma, R. et al. 2001; Elzen, B. et al., 2008; Kern, R. et. al., 2001; Rotmans, J., 2001; Geels, F.W.,2002; Kemp, R. and Rotmans, J., 2004).

According to Perrels, A. (2008), transition policy translates some insights from evolutionary economics and operationalizes them into innovation governance. Here, stepping back from a deliberated form of transition policy, the author likes to gain some advice from general policy theory and its insights. Similar to what transition policy emphasize, multi-actor aspects became widely recognized in modern public policy study. Bressers, H.Th.A. and O’Toole, L.J., (2005) explained, multiple actors are ‘networked’, ‘operating not as autonomous/atomized unit, nor merely as parts of a larger straightforwardly hierarchical array but in a matrix of interdependence (Bressers, H.Th.A. and O’Toole, L.J, 2005:140)’. Modern public policy theory focuses on ‘policy networks’ rather than public administration. This policy networks study has been widely spread after the 80s (Bressers, H.Th.A., 2009), analyzing the relationships between public authorities and other socio-economic actors in policy process. Within these networked actors, some actors are directly or indirectly involved in decision making process and others are not so much. Here, the author wishes to distinguish the former group of networked actors as a ‘policy network’ and the latter as ‘networks of actors’. This distinction will be utilized in the following analytical framework of factors.
In modern public policy and public management, the government became no longer a sole player but a part of decision makers. Thus, a phase, ‘from government to governance’ is often quoted. Many scholars introduced various forms of governance, highlighting the role of social actors. In an extreme case, some advocate ‘minimal state’, neglecting the important role of government. The author believes, however, that the role of government has not declined in modern governance but rather increased its importance. Definitely, the function of government has changed or has to change to drive desirable policy outcomes. This functional change often requires governments to obtain better knowledge and skills in public management. Some describe it as ‘smart government’ (Fischer, F. et al, 2007)

Policy network studies reveal close inter-linkages among the characteristics of a network of actors, the selection of policy strategies and measures, extent of resource allocation and responsibility, and also the results of policy implementation (Bressers, H.Th.A. and O'Toole, L.J., 1998). The linkages of the different components in modern public policy are well described in governance theory.

Governance theory, regardless of being interpreted in many ways, started with multi-actors perspectives (both horizontal and vertical) of modern public policy and management. It focuses on the interconnection and interaction among multi-actors and other policy components such as problems, strategies and instruments, and resources that contains ‘multiplicity’ characters in policy process. Thus, governance study analyzes multiple components within a system; some refer to it as ‘regime’. Bressers, H.Th.A. and Kuk, S.M., (2003) well elaborate governance theory, proposing five elements: 1) multiple levels and scales; 2) multiple networks of actors; 3) multiplicity of problems and goals; 4) multiple strategies and instruments; and 5) multiple responsibilities and resources for implementation. These five elements operate in a regime, creating a rule of game and certain contextual features and proceeding specific institutionalization.

Two main streams of governance studies are: 1) design perspective governance in order to improve the efficacy of public policy and 2) dynamics perspective governance to understand the complexity of an existing regime (Voß, J.P., 2007). Voß, J.P., (2007) emphasizes the need of an integrated approach in governance study, arguing design and dynamics are two side of a coin. Similarly, Bressers, H.Th.A. and O'Toole, L.J., (2005) emphasized the importance of contextual understanding in policy analysis and design, while explaining that the context is created by continuous policy interactions among multi-actors (Bressers, H.Th.A. and O'Toole, L. J., 2005).

Bressers, in his early work on policy implementation theory and later on his ‘contextual interaction theory’, argues the benefit of considering actor-oriented variables, such as ‘motivations, cognitive knowledge and information, power and ability’, in understanding the dynamics of governance and also the plausible results of policy implementation (Bressers, H.Th.A. and O'Toole, L.J., 1998). As a long history of policy implementation studies proved, certain policy and policy instruments do not always bring anticipated outcomes as they are greatly affected by certain institutional settings (Lundvall, B.A., 1992). Policy intervention results depend on networks of actors and their key variables of influence. Vice versa, the selection of policy instruments should be based on serious consideration of such actor-oriented variables. In doing so, it can increase the probability of achieving desired policy outcomes (Bressers, H.Th.A. and O'Toole, L. J., 2005).

1.3. Framework of designing factors for effective innovation policy

After reviewing various literatures, the author extracted some determinant factors to be considered when designing policy that can effectively drive environmental innovation and sustainable system change. The following framework is a synthesis of a range of innovation policy, transition policy, public policy, and governance theories. The following order does not represent the level of importance.

Formulate a policy network of decision with visionary and influential actors from public and private domains

As transition management policy indicates the importance of transition arena, the role of decision makers is critical as they can set a clear scene of sustainability. Members of decision makers should be carefully selected, ensuring they are visionary players who can take challenges and transform them into opportunities to build sustainable systems. As transition policy advocates in their later studies, it is beneficial to also include influential actors both from public and private domains in a policy network of decision.

Set a clear vision and maintain it regardless of leadership/government change

A system change is a rather long process that requires consistent efforts towards clearly set direction. A vision is a critical component that can guide clear direction to networks of actors. To set a clear vision is the first step of innovation policy design. More importantly, the vision needs to be maintained in a set timeframe regardless of government and/or leadership changes. Often, a change in government will affect policy focus or direction that may be different than previously set ones. Otherwise, it will provide uncertainty for networks of actors and annul the progress.

Aligning with a vision set, it is beneficial to promulgate practical and achievable action plans in a certain period of time, while ensuring a room for revision along the way so that feedbacks and learning can be incorporated. These plans should include measurable indicators, both quantitative and qualitative, which would be clearly helpful in assessing any progress so that the plan can be more real and manageable.

Set proper scoping/extent but ensuring adaptive approach incorporating learning

Action plans that are previously discussed would be set with some strategic choices of focus. These choices reflect how policy scope is set. It is important to set the scope properly. A larger scope can include larger groups of networked actors benefitting them. However, it might be risky to lose the focus of policy efforts that are deliberately designed. Nevertheless, environmental innovation often depends on other dependent technologies and their level of maturity. Therefore, it would be beneficial not to focus on picking winners but to properly set an extent, wide enough, so that it opens up more possibility to induce a wider range of innovation. Also, it is critical to signal larger networks of actors and to make them acknowledge a bigger wave of innovation efforts (changes in regime conditions), which eventually would make changes in a system.

Appropriate mix of policy measures, including both demand- and supply-side measures, providing continuous incentives

Innovation and system change is a complex process where different stages of innovation and diffusion interact in multi-
opportunities and networks of actors. Clear actions. This applies not only to various administrative levels of responsibilities, and to indicate clear accountabilities of their investment. Therefore, ‘smart’ resource allocation of public funds is critical, to allocate sufficient public funds. In cases of committed to pursue changes toward sustainability, it often faces difficulty to allocate sufficient public funds. In cases of R&D stage. Thus, timing to implement various policy measures is also another important factor.

Set clear responsibilities and strategically allocate resources so that they can further activate networks of actors and stimulate the utilization of their own resources

Taking into consideration the engagement of multiple actors in governance, it is essential to allocate clear roles and responsibilities, and to indicate clear accountabilities of their actions. This applies not only to various administrative levels of public authorities but also to networks of actors. Clear responsibility and accountability of associated actors will facilitate implementation process and result in desirable outcome generation.

Often the level of allocated resources for implementation reflects the level of commitment. Even though the government is highly committed to pursue changes toward sustainability, it often faces difficulty to allocate sufficient public funds. In cases of developing countries, the issue becomes much more serious. Therefore, ‘smart’ resource allocation of public funds is critical, so that limited public resources can be utilized in a way that it can activate networks of actors and draw their private resource investment.

Ensuring ‘coherence’ in every aspect of governance:

Throughout various public policy and governance theories and studies, ‘coherence’ is most frequently identified as one of the most critical element. The multiplicity of governance creates complexity and high level of dynamics in governance system. Governance for innovation and system change, in particular, bears ‘evolvement’, which adds more complexity and dynamics to it. Therefore, a chance to be fragmented is higher, derailing from coherent governance system.

Various types of coherence can be identified, but they can be categorized differently depending on how you look at. Here, internal coherence is considered as coherence within governance associated with specific objectives, while external coherence is coherence across other existing governance regimes (cross sectors, for instance) towards sustainability. Internal coherence within one governance regime contains: coherence between vision and short-term strategies and action plans, coherence within public administrations, and coherence among various instruments in place. Coherence will increase certainty to networks of actors, ensuring consistent and continuous efforts to be in place toward a long-term system change. It will increase the efficacy of a set of policy instruments. It will ensure a common ground so to enhance cooperation among networks of actors.

Thorough and continuous assessment of networks of actors

Policy implementation study emphasizes the importance of understanding networks of actors in connection to results of policy implementation. As Bressers, H.Th.A. (2004) describes, the levels of actor-oriented factors, especially ‘motives, cognitions, and resources’, are critically affecting the dynamics of governance and its outcomes. The selection of measures should be done reflecting these factors and ensure proper assistance and support to be made in order to enhance weaker elements.

During the process of innovation and system change, the evolvement of actors’ motivation, cognition and power would occur. Therefore, the assessment of networks of actors needs to be conducted in a regular base or in a continuous manner, rather than one-time assessment.

Maintaining adaptability to incorporate ongoing learning:

In modern policy design, various tools to project future sustainable system have been utilized, including road-mapping, forecasting, back-casting, scenarios development, and others. Nevertheless, ranges of unknown variables would appear in every step of the way towards sustainable system change. Therefore, it is absolutely essential that feedbacks and learning must be well incorporated so to maximize the progress.

2. ENVIRONMENTAL AND SOCIOECONOMIC LANDSCAPES OF AUTOMOBILE INDUSTRIES IN US AND JAPAN

Prior to case studies on US and Japanese governance on environmental car innovation, this section provides short descriptions on socio-economic landscapes of automobile industries in the US and Japan. It also illustrates environmental and economic drivers of why US and Japan were far early in setting up environmental policy measures for cars. The description hopefully will support a better understanding of environmental product innovation processes in both countries.

The US is the most car-oriented society in the world: Most urban structure was developed in a way that living without a car is nearly impossible (Gertz, C., 2003). Since the decision to build the interstate highway system by the Federal Aid Highway Act in 1956, the US transport policy drove the construction of extensive road networks and pre- eminent highway infrastructure. During the 25 years of highway system construction, no Federal investment was allocated in public transit (Gertz, C., 2003). Thus, it resulted in limited or absence of significant alternatives to highway travel. Such ‘highway only’ policy has not changed until 1991 when the Intermodal Surface Transportation Efficiency Act (Gertz, C., 2003). Unwillingness of the US government to heavily tax motor fuel also supported “perception creation” that highway travel is an economic necessity (Greene, D.L. and Wegener, M., 1997).

The US transport policy greatly supported automobile industry to grow. Big three US carmakers became mega companies contributing a large portion of the US economy. Until the 80s, their market domination made them stagnant in an absence of
major threat (Wallace, D., 1995). Using their economic power, the US carmakers were superior to any regulatory pressure.

Automobile industry in Japan, on the other hand, has very different background. In the post war era, the first priority of the Japanese government was restructuring destroyed Japanese industries, which was only one-seventh of pre-war production level in mining and manufacturing sectors. The Japanese Ministry of International Trade and Industry (currently named as Ministry of Economics, Trade and Industry) was established with designated strong power. Its mandate was to lead industry restructuring and economy development process. The ministry of industry determined which sectors to be promoted or not (Imura, H., 2005a). With exclusive power to control most manufacturing industries and the energy sector, the ministry of industry articulated exerted various measures like direct regulation, financial assistance through tax incentives, policy oriented loans, and various forms of informal communications, and administrative guidance to promote and de-promote so-called sunrise and sunset industries (Watanabe, C. and Honda, C., 1991; Imura, H. 2005a). The 1952 Industry Rationalization Promotion Law, supported by METI, designated automobile industry as one of key industries for the Japanese industrial growth (JAMA, 2008).

The Japanese automobile industry had grown rapidly throughout the mid 50s, 60s and 70s. One major events to influence this growth was the 1955 ‘people’s car’ plan, supported by the Japanese ministry of industry. It greatly stimulated the competition among the Japanese manufacturers, resulting in knowledge accumulation through co-production with oversees manufacturers; steady increase in car sale; large scale of investment to advance production technologies; and others (JAMA, 2008). ‘Competitiveness’ has maintained high. Unlike US automobile industry, a larger number of car manufacturers were competing. Older firms like Toyota and Nissan and numerous newer entrants competed, and aggressively investing in technology development (Wallace, D., 1995). Deliberated government efforts to support automobile industry and high competitiveness within the industry were adding factors to build strong cooperative relationships with regulators and regulatory pressure in Japan.

Even though the two countries have different background of automobile industrial growth, they shared common environmental problems. During post war era, deteriorated air quality, especially in urban areas, became severe as they experienced progressed and rapid industrial and urban growth. Increasing vehicle use was one of the most outstanding contributors to serious local air pollution. As a result, both countries introduced vehicle emission regulations in the 1960s, far earlier than other countries. Vehicle emission regulations had greater effects on vehicle technologies, even though it also translated into financial burden for automobile industries.

In the Japanese case, both government and industry were highly sensitive on US regulatory changes as they wished to penetrate the US car market and expand their market share. US had been the biggest export market for the Japanese car makers. To support the Japanese automobile makers and their early preparation for relevant technology development, the Japanese government closely watched any changes in US regulations and often adopted similar regulations as US. Since the 80s, the Japanese car makers rapidly increased their market share in the US vehicle markets. Regulatory development in Japan was driven not only by environmental concern but also by economic rationale.

3. EARLY BATTLE ON VEHICLE EMISSIONS CONTROL TECHNOLOGY: 1960-1980

The following two sections (section three and four) are heavily based on secondary literatures. The author acknowledges the excellent work of quoted researchers. This section illustrates different governance patterns in the US and Japan around early vehicle emission regulations and their effects on catalytic converters innovation and diffusion.


Like other US cities, California faced a serious air pollution problem since the 1950s due to increasing industrial activities, rapid urbanization and urban sprawl, consequently fast growing population and vehicle fleets. Large parts of California, in particular the LA basin, had shown unacceptably high levels of pollutants of nitrogen oxides (NOx), volatile organic compounds (VOCs), and ground level ozone. And road vehicles were the major source of these pollutants (Wallace, D., 1995). This environmental challenge drove California to stand upfront in vehicle emissions control regulations.

In 1960, the Motor Vehicle Pollution Control Board was established in California and focused on technological solutions to vehicle emissions (Wallace, D. 1995). The Board introduced the first automotive emissions control technology, positive crankcase ventilation to control hydrocarbon (HC) emission since 1961 (CARB, 2010). Later on, the Board adopted auto tailpipe emission standards for HC and carbon monoxide (CO) in 1966. After merging with the Bureau of Air Sanitation and its Laboratory, the Board was renamed as the California Air Resources Board (CARB, 2010).

Inspired by California’s efforts to control vehicle emissions, the US federal government enacted the US federal Motor Vehicle Act and started federal research to address air pollution from motor vehicles (CARB, 2010). While the Federal Clean Air Act of 1963 only tackled stationary emission sources, the US Congress prepared for future regulation on motor vehicles. The US Congress directed the Secretary of Health, Education, and Welfare to set the first national emissions standards for light-duty vehicles. The 1965 Motor Vehicle Air Pollution Control Act came into force, modeling after the California vehicle emission standards, and required all 1968 models to reduce several 1963-base emissions: a 72% reduction of HC, 56% reduction of CO, and a 100% reduction of crankcase HC. Also the National Air Pollution Control Administration was established, taking responsibility for future pollution control efforts (Kubiszewski, I., 1969). Two years later, the 1967 Air Quality Act, amendment to the 1963 Clean Air Act, pre-empted other states than California from regulating vehicles emissions separately (Gerard, D. and Lave, L.B., 2005). However, the Air Quality Act of 1967 was surpassed by the far more aggressive Clean Air Act of 1970. Other regulations prior to the 1970 Clean Air Act were not influential but provided an opportunity to regulate powerful automobile industry (Gerard, D. and Lave, L.B., 2005).

In the mid 60s, the US automakers went through a difficult time failing to earn trust both from the public and the government. Besides series of incidents relating to auto safety issues, the US
under the condition that the US EPA could ensure unleaded gasoline available in the market (Gerard, D. and Lave, L.B., 2005). And in 1973 the US EPA promulgated a gradual phase-out of lead in gasoline and required the general availability of one grade of unleaded gas by July 1, 1974, in order to protect the catalytic converters to be installed in 1975 (USEPA, 1973). However, GM broke its promise to install catalytic converters and requested for the delay, because GM recognized potential cost savings from not having catalytic converters. In addition, R&D activities on catalytic technologies by GM and Ford turned out to be bogus and no competition between two did exist (Gerard, D. and Lave, L.B., 2005). Meanwhile, Japanese automakers developed another technology, stratified-charge engine and met the standards. Honda and Mazda were already demonstrating prototype cars and Senator Muskie rode one during his visit to Japan in 1973.) (Wallace, D., 1995).

Regarding NOx standards, a targeted technology was a three-way catalyst. Three-way catalysts needed a computerized system to control function properly. Thus, it was rather complex and expensive technology comparing to catalytic converters (Gerard, D. and Lave, L.B., 2005). A lack of industry’s efforts failed to produce vehicles that could meet NOx standards. In 1977, the US automakers insisted to produce 1978 model cars without meeting the standards. As the law prohibited putting the cars into market without a certification of approval, it ended up having piles and piles of new cars packed around their plants (Gerard, D. and Lave, L.B., 2005). The US Congress was forced to make a decision whether facing their auto-industry shut-down by not allowing their sales without certification, or consistently pushing the standards as they initially planned. The US Congress made a decision to avoid economic crisis and passed the 1977 amendments to the Clean Air Act. As a result, less stringent reduction of nitrogen oxides (75% reduction, while the original 1976 NOx standards required 90 % reduction) was set for 1981. Also it pushed back HC and CO standards to 1980 and 1981 instead, and allowed the possibility of CO waivers (Gerard, D. and Lave, L.B., 2005). By 1981, the US automakers started installing three-way catalysts. However, according to Gerard, D. and Lave, L.B. (2005), it was not merely driven by regulations but mostly by public’s heavy criticism on vehicle quality.

3.2. The Japan Vehicle Regulations, Deliberate Support for the Japanese Automakers

Rapid industry recovery in a post war era, Japan faced severe environmental pollution issues, including deteriorated air quality. Strong concern on air pollution drove public demand to regulate various emissions sources. As a result, the Japan Ministry of Land, Infrastructure and Transportation (currently named as Ministry of Land, Infrastructure, Transportation, and Tourism) issued the Motor Vehicle Exhaust Emissions Standard in July 1966, ruling 60% reduction of CO (JAMA, 2008). However, the standard was already met easily by existing vehicle models. Thus, no contention was made. Only it provided regulatory boost for the Japanese automakers to produce cars with better engine and exhaust design (Wallace, D., 1995).

Japan continued to introduce a number of vehicle emission regulations in the 70s. The government issued the 1973 Emissions Control Standard, adding HC and NOx emissions. This was driven by the US regulatory movement towards tighter control of vehicle exhaust gas (Imura, H., 2005b). The intention was clear, ensuring vehicle export to the US market. By adopting similar regulations, the Japanese automakers can invest on emission control technology and prepare upcoming market

Such regulatory development by the Japanese government was in alignment with the 70s vision set by the ministry of industry. The Japanese ministry of industry had a unique way of policy making: a 10-year cycle ‘vision’ and vision-oriented policy making to pursue ambitious industrial development (Watanabe, C., 1999; Åhman, M., 2006). The vision sets priority areas and provides a common ground and direction for networks of actors including public agencies, industry, and local communities to follow (Kazunori, Y., 1997; Åhman, M., 2006). While the vision of the 1960s was focusing on heavy chemical industry, the strategic vision of the 1970s changed into heavily investing knowledge-based industry. As mentioned earlier, automobile industry was one of the strategically selected industries. Also, the government support for automobile sector was aligned with the 70s’ Japanese technology policy: In the 60s, the Japanese technology policy focused on imported technologies but changed its focus to domestic technology innovation and improvement since the 1970s (Watanabe, C. and Honda, C., 1991).

The vehicle emissions regulation in Japan was not solely driven by economic rationale. It also benefited the Japanese government to fulfill the public demand to improve air quality. For that reason, the Japanese government continued to make stringent emissions standards such as the 1976 Emission Control Standard with the most stringent requirement to reduce NOx emissions (no higher than one-tenth of the pre-1973 level) by 1978 (JAMA, 2008). Even though Japan had to agree exemption of foreign cars from the Japanese 1976 standard due to strong US lobbying (Wallace, D., 1995), it certainly showed the Japanese government’s continuous efforts pursuing one direction.

4. PUSHING FOR ZERO EMISSIONS VEHICLE INNOVATION AND DIFFUSION

Innovation around zero emission vehicle development is another comparative example to evaluate the role of government and public policy. The following section provides details how the US and Japanese governments approached to promote environmental vehicle innovation and diffusion.

4.1. US efforts to promote electric vehicles and alternative fuels cars

The interest on electric and hybrid engine technology existed at the US federal government level even in the mid 70s. That interest was reflection of the 1973 oil crisis (Hybrid cars, 2010). The US government funded two programs to advance electric and hybrid car technology in 1975 and 1976. The Electric and Hybrid Vehicle Act was introduced in 1976, aiming to work closely with industry to improve batteries, motors, controllers, and other hybrid-electric components. GM had shown interest in hybrid technology even on the late 60s and the 70s. In the late 70s, GM made serious R&D investment on electric cars and signaled possible production in the mid-80s (Hybrid cars, 2010). However, GM’s interest died with conclusion that internal combustion engine to be more competitive choice (Hoyer, K.G., 2008).

In the early 90s, the interest was regained by the support from government and automakers partnerships under the Clinton administration ideology (Hoyer, K.G., 2008). At a provincial level, Californian regulators were very interested in electric vehicles as a solution for urban air quality improvement. While facing serious traffic congestion and unresolved air quality deterioration, the Californian government tried many different options, including ride-sharing promoted by adding special lanes and enhancing vehicle inspection. As the political and social pressures at that time excluded a possibility to restrict increasing vehicle use (Wallace, D., 1995), only limited choices remained. After revealing inability to resolve these issues and ruling out the possibility to introduce toll fees and/or congestion charges, the regulators ended up tightening up exhaust emissions standards (Wallace, D., 1995). As a result, they introduced zero emission vehicle (ZEV) regulation with intention to target electric car promotion.

Around the late 80s, GM was ambitious again for electric car development with a leadership from the top management. To regain market share from the Japanese car invasion, it was a strategic economic choice for GM. GM presented ‘Impact’ model, an electric car at the Los Angeles motor show in early 90s and received good public response. Such response led GM to commit ‘Impact’ commercialization. GM’s announcement also encouraged CARB to go ahead with the zero emission vehicle regulation (Wallace, D., 1995). In 1990, CARB promulgated a rule for minimum requirements of zero emission vehicle sales by large automakers: 2% sale in 1998-2000, 5% in 2001-2002, and 10% in 2003 and beyond. High level fine of 5,000 USD was attached to the rule (Wallace, D., 1995).

The zero emission vehicle regulation had another political and economically motivation drivers. Facing a serious economic recession, the Californian politicians were keen to find a way to save high-tech and well-paid jobs that were used to be provided by defense industry and also to utilize technologies and expertise accumulated during defense industry boom. The prospect of electric vehicles was well fit. However, according to Wallace, D. (1995), the latter reasoning did not move the CARB regulators but the GM’s commitment did. They assumed GM’s market and technology assessments were correct and electric cars would soon be introduced. Thus, the zero emission vehicle regulation was actually a market-forcing tool rather than technology forcing one (Wallace, D., 1995). However, the changes in leadership at GM and critical economic difficulty that GM faced at that time led to abolishment of electric car development in the early 1993 (Wallace, D., 1995). No other US automakers showed interest or commitment on electric car development.

4.2. Japanese long-term vision for new generation cars innovation and diffusion

The Japanese industry ministry announced the development of new generation cars from the early 70s as one of mitigating means for local air pollution problems and oil-dependency. Visioning battery-powered electric vehicles as the most interesting option, the Japanese ministry of industry commenced a five-year government-industry research and development program in 1971 (Åhman, M., 2006). The project was also aligned with the Japanese strategy of innovation technology policy to promote new energy and energy-saving technologies in the 70s: The Sunshine Program was R&D program for new energy technologies, while the Moonlight program was for energy-saving technologies The former was launched in 1974 and the latter in 1978 (Minoru, S., 2009). According to Åhman, M. (2006), over 2.2 billions Japanese yen of government fund were allocated each year between 1971 and 1975, which was...
only covering targeted efforts for vehicles without general R&D fund for energy, general automotive and electrochemistry research (Åhman, M., 2006).

R&D support had been one of focal instruments of the Japanese innovation technology policy especially during the period of industrial restricting and high-growth. Between 1978 and 1996, the Japanese ministry of industry continued R&D funding mainly through R&D consortia. The Japanese consortia were modeled after the British research association system (Minoru, S., 2009). The strategy around the creation of consortia was the particular intention to induce private funded research and development. The consortia during this period included R&D on automobile and battery technologies.

After the five-year R&D program (1971-76), the ministry of industry introduced a basic market expansion plan for battery-powered electric vehicles in 1976. It was a comprehensive commercialization plan, aiming to remove obstacles for technology development by amending laws and taxes, creating new standards and building fuelling infrastructure (Iguchi, M., 1992, quoted in Åhman, M. 2006). Due to slower technology development and stabilized oil market, the first market expansion plan was revised in 1983 (considered as the second market expansion plan) earlier than initially planned (Iguchi, M., 1992, quoted in Åhman, M., 2006).

Japan regained strong interest on electric vehicles when California announced zero emission vehicles regulation. Also the 1992 Rio summit on sustainable development greatly influenced the Japanese government. Thus, global environmental and energy issues became an important political agenda in Japan. The ministry of industry reconsidered battery-powered electric vehicles as a long-term sustainable vehicle option and launched the third market expansion plan in 1991 with more aggressive targets of 200,000 electric vehicles to be on the road by 2000 (Åhman, M., 2006). For industry, the Japanese automakers were convinced by the California zero emission vehicle requirements and invested on electric vehicles with more serious measures (Mauro, K., 2000 and Patchell, J., 1999, quoted in Åhman, M., 2006).

The Japanese ministry of industry recognized a priority need to advance battery technology, which is considered as a key component for electric car innovation success. In 1992, a project on lithium batteries development began as a part of the New Sunshine program (Åhman, M., 2006). As a result, Li-ion battery was developed by Shin-Kobe Electric machinery (Terada et al., 2001, quoted in Åhman, M., 2006). Besides, a number of collaboration projects between automakers and battery manufacturers occurred and enabled them to keep future battery options open (Patchell, J., 1999, quoted in Åhman, M., 2006). Considering high certainty of future battery technology market, open-end approach was wise.

Besides R&D and commercialization supports, Japan also put efforts on building a proper system of provision. In 1993, the ‘ECO-Station’ project was launched in order to build 2000 fuelling stations for clean energy vehicles by 2000, half of which were intended as battery-powered electric vehicle charging stations (Hayashi, E. et al., 1994, quoted in Åhman, M., 2006).

In the mid 90s, the Japanese government introduced various measures to support technology diffusion. In 1995, as a part of the Japanese environment conservation program, the government announced 10% replacement of public vehicles with low emissions vehicles by 2000. A purchasing incentive program for battery-powered electric vehicles was also introduced in 1996, replacing existing leasing and purchasing incentive programs that were running since 1976. This purchasing incentive program subsidized 50% of the extra incremental price for an electric vehicle and resulted in the introduction of 117 electric cars during the first two years (Åhman, M., 2006). However, outcomes were not successful. The burst of the Japanese bubble economy and consequent economic turbulence made difficult for public agencies and local governments to afford expensive electric vehicles. Thus, they could not fulfill the targets of the 1995 procurement policy: only a few battery powered electric vehicles were actually in use (Åhman, M., 2006). The economy turn-down also affected the infrastructure ECO-Station program: by 2000, only 36 stations were built for battery powered electric vehicles (Chiba, A., 2002, quoted in Åhman, M., 2006).

In 1995, the Japanese ministry of industry launched a battery-powered electric vehicle field test in order to assess the progress of technology innovation. The result of 1996 revealed that the targets set by the industry ministry’s third expansion plan would not be met (Patchell, J., 1999, quoted in Åhman, M., 2006). Slow development pace and low market response made the ministry of industry to reconcile ‘electric vehicles-only’ strategy. While being aware of the US Partnership for a ‘New Generation of Vehicles’ program and its focus on hybrid electric cars, the Japanese ministry of industry and the National Energy Development Organization (NEDO) commenced an ‘Advanced Clean Energy (ACE) vehicle’ program in 1997. The ACE program changed at last minute when Toyota announced a flagship hybrid car, Prius to be released. This five year program planned to develop different advanced energy efficient hybrid cars (Åhman, M., 2006).

Between 1976 and 1993, the Japanese government funds that are allocated to support all relevant activities for electric car innovation were relatively low (Åhman, M., 2006). Åhman, main (2006) estimated a total investment cost per vehicle within the leasing program between 1976 and 1996, which was approximately 14,400 USD (one third relates to R&D, another one third to market support and the rest one third to fuelling infrastructure). No information was available to oversee private sectors investment on relevant technology R&D.

Continuous government supports for electric cars innovation, commercialization, and even infrastructure building made great influence and benefited hybrid car innovation. In particular, the Japanese automakers utilized the knowledge accumulated in R&D activities around battery-powered electric vehicles in the development of hybrid car. Market support efforts also signaled the clear government commitment to promote new future generation cars and reduced uncertainty for industry so to continue investing in new car innovation. As Åhman, M. (2006) stated, the long-sustained government efforts through various support measures resulted in “a system where the sustained efforts created feedback to the R&D process from early market experience and the possibility of accumulating and maintaining knowledge, even when interest and support were low (Åhman, M., 2006: 441)”. In this respect, the efforts put into electric vehicles have contributed to the unintentional success of hybrid car innovation.

5. LESSONS
Historical events relating to passenger car innovation in US and Japan provide some valuable lessons. Both countries faced similar environmental pressure from deteriorating air quality,
which led to regulating vehicle emissions earlier than any other countries. However, the two countries had a very different regime background. Throughout the 60s up to the 90s, the big three automakers in US were lacking motivation to pursue continuous improvement and innovation but obtained a superior knowledge over the US government authorities (Wallace, D., 1995). With their superior knowledge and a large contribution to the US economy, they were able to manipulate the US authorities. Since the 80s, the US automakers started to face their Japanese competitors, but they did not transform this challenge into positive improvement. As a result, the US automakers failed to compete with the Japanese automakers in zero emission vehicle markets until the beginning of the new century. The US authorities, on the other hand, have shown some sporadic leadership to push environmental innovation in the US automobile industry. However, the lack of coherence between the regulator and the administrator, and the inconsistent political position jeopardized the regulator and the administrator, and the inconsistent opportunity to pave the road for a new trend in international development in other countries. However, the two historic events (section three and four) show that the awareness, fast learning, and early adoption of innovative policy provided a better opportunity to pave the road for a new trend in international markets. Japan had totally different circumstances than the US situation. To recover from the destructed economy and industry, the Japanese government had projected a clear vision and commitment to pursue technology advancement as a strategy to gain international competitiveness. The Japanese government provided consistent and focused assistance to industries to support their growth. Based on trust, the industries were compliant to the government. Thus, stringent regulations functioned as a clear signal and stimulant to the industries rather than confronting threat. These contextual factors greatly affect the final outcomes in passenger car innovation in Japan.

There are few other lessons that can be learned from the Japanese government role in the development of new generation cars. First, vision-oriented policy design performed by the Japanese ministry of industry is a unique highlight. The vision shows a clear direction and all activities are designed accordingly. Regardless of oil crisis and bubble economy burst, the vision seemed to be maintained, even though the results of policy implementation were affected by the economic difficulty. For instance, public agencies and local governments failed to meet the targets of the 1995 procurement policy for battery-power electric vehicles during the economic recession.

Another lesson relates to the timely implementation of supply and demand-side support measures. As Åhman, M. (2006) emphasizes, the introduction of demand-side measures like procurement policy should be timely aligned with R&D support. Especially when it comes to uncertain technology innovation policy, it is more critical to provide a clear and solid signal by introducing both supply and demand side measures in a similar timeframe. The Japanese case clearly showed its success by doing such.

The both historic events (section three and four) show that the Japanese government has been quite sensitive about policy development in other countries. The awareness, fast learning, and early adoption of innovative policy provided a better opportunity to pave the road for a new trend in international markets. Japan had been quite successful in learning from the international experiences. Often introducing new policy with environmental progression faces harsh resistance and confrontation from domestic market players. However, this was not the case for Japan due to the strong trust among networks of actors and the government that were built for a long period of time.

CONCLUDING REMARKS

Combating climate change has been a priority agenda for many governments. All the components that are contributing to climate change are deeply embedded in our society, which may require a rapid paradigm shift. To advance a paradigm shift or a system change all society actors need to proactively participated in changes toward sustainability. Here, it is difficult to discount the importance of government role to activate these actors in a more effective manner. This paper presented an attempt to identify determinant factors to be considered in policy design for innovation and sustainable system change. Using historic events in two different countries, the author tried to test these theory-driven factors and further extract some lessons on the role of government. In addition to the substantial design factors: such as vision setting, a proper mix and implementation timing of policy measures, coherence within internal government administration, and consistent policy execution, the author recognizes the importance to understand the contextual background, which includes actor-specific characteristics of both public and private players and their relationships, in order to design effective policy.

This paper did not aim to evaluate overall US and Japanese sustainable innovation policies. For that reason, it did not include any recent development around new generation car development since the hybrid car success. Toyota’s hybrid car success certainly changed the landscape of car markets and stimulated active progression on new vehicle technologies, including the revitalization of electric vehicles development in many other countries. It would be of high interest and importance to study other countries’ policy efforts on this development.

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