Energy Policy 56 (2013) 248–258

Contents lists available at SciVerse ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Energy efficiency in the Japanese transport sector ☆

Phillip Y. Lipscy *,[1], Lee Schipper [2]

Department of Political Science and Shorenstein Asia-Pacific Research Center, Stanford University, 616 Serra Street, Stanford CA 94305-6044, United States

HIGHLIGHTS

- ▶ We examine energy efficiency in the Japanese passenger transportation sector.
- ▶ Japan stands out for low activity and modal structure, not modal energy intensity.
- ▶ We also consider the political context of energy efficiency in Japan.
- ▶ Energy efficiency policies also rewarded important political constituents.
- ▶ Political changes are threatening transportation energy efficiency in Japan.

ARTICLE INFO

Article history:
Received 22 February 2012
Accepted 15 December 2012
Available online 26 January 2013

Keywords:
Japan
Transportation
Efficiency

ABSTRACT

We examine energy efficiency in the Japanese transportation sector since the 1970s. Comparisons with the United States and other developed economies illustrate that Japan primarily stands out due to low activity levels and modal structure rather than modal energy intensity. On-road automobile energy intensity has shown little improvement, albeit from a low base, over the past four decades. We also consider policy measures undertaken by the Japanese government. Political arrangements in Japan after World War II made it attractive for politicians to pursue energy conservation by making transportation, particularly by automobile, expensive for the average Japanese citizen. The revenues raised from various fees and taxes on automobile transportation were redistributed to core supporters of the ruling Liberal Democratic Party. These political arrangements have come under fire in recent years, calling into question Japan's traditional approach towards transportation sector energy efficiency.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

Japan has one of the most energy efficient economies in the world according to conventional measures such as energy intensity. The Japanese transportation sector is also among the most efficient. In this paper, we will review energy trends in the Japanese transport sector in recent years. We reveal that the low level of automobile ownership in Japan through the early 1970s was largely erased by steady growth that pulled fuel use upwards as the Japanese became more affluent and automobile ownership increased. Poor traffic hindered Japanese drivers from attaining high levels of fuel economy. Only after 2000 did these trends begin to change and even reverse. Thus, despite Japan's global reputation as an energy efficient country, energy intensities for the main mode of transport rose for most of the period after 1973.

Japan clearly stands out from other countries in transport activity and mode share. We will illustrate this point through comparison with the United States and several other developed countries. Despite economic development to a level comparable to most Western countries, Japanese travel shorter distances and are much more prone to travel by rail. After declining consistently for several decades, rail share in Japan has rebounded over the past decade. Past analyses have called into question whether Japan's transportation energy efficiency is attributable to government policy (Kiang and Schipper, 1996). We consider several non-policy

☆ This article was developed largely as a co-authored, collaborative work. Lipscy was solely responsible for finalizing the draft and making subsequent revisions and edits. We thank Yasuhiro Daisho, Akihiko Hoshi, and Takashi Naono, as well as members of the following organizations, who were exceedingly generous with their time and resources: METI, MLIT, IEEJ, JARI, NTSEL. We thank Siddharth Bellur, Trevor Incerti, Erica Kang, Jared Poelman and Zheng Wu for excellent research assistance. The broader project of which this draft is a part has benefited greatly from the support and generosity of Sakurako and William Fisher, the Japan Foundation Center for Global Partnership, the FSI Takahashi Fund, the Japan Fund at Stanford University, Shorenstein APARC, and the UPS Endowment Fund at Stanford University.

* Corresponding author. Tel.: +1 650 725 8867.
E-mail address: plipscy@stanford.edu (P.Y. Lipscy).

[1] Assistant Professor of Political Science and The Thomas Rohlen Center Fellow at the Shorenstein Asia-Pacific Research Center, Freeman Spogli Institute for International Studies.

[2] Deceased author. The late Lee Schipper was a Senior Research Engineer at the Precourt Energy Efficiency Center, Stanford University, and Research Scientist for the Global Metropolitan Studies Center, University of California, Berkeley.

0301-4215/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enpol.2012.12.045

determinants of transportation trends—geography, urban population density, demographics, and economic development—and find that Japan stands out in terms of transport activity and mode share even after considering these factors.

Turning to policy, a primarily focus in recent years has been the use of regulatory means to improve automobile fuel economy, exemplified by the Top Runner program. However, the defining feature of transportation policy in Japan is high costs imposed on automobile ownership and travel. Highway tolls in particular are extremely high compared to other developed economies. Political arrangements in Japan after World War II made it attractive for politicians to pursue energy conservation by making transportation, particularly by automobile, expensive for the average Japanese citizen. The revenues raised from various fees and taxes on automobile transportation were redistributed to rural residents and the construction industry, the core supporters of the ruling Liberal Democratic Party. These political arrangements have come under fire in recent years, calling into question Japan's traditional approach towards transportation sector energy efficiency.

2. Japan's transportation sector in comparative perspective

2.1. CO_2 emissions in the Japanese transportation sector

In this section, we will place Japan in comparative perspective through comparison with the United States. We will divide transportation into passenger transportation and freight transportation, since these subsectors tend to be driven by different economic factors (Schipper et al., 1997; Schipper and Marie-Lilliu, 1999). This omits a small amount of energy in the transport sector for off road vehicles (U.S. Department of Energy, 2010). The overwhelming bulk of the energy for domestic passenger transportation and freight transportation consist of the following vehicles:

Passenger transportation

- Cars (private vehicles like sedans, kei-cars (the smallest category for cars in Japan, length < 3.4 m, width < 1.48 m, height < 2.0 m, engine displacement < 660 cc), Sports Utility Vehicles (SUV) and Passenger Light Trucks (LT) for passenger use in the U.S. For Japan, kei-cars are included here; for the US, the share of light trucks and SUV used as household vehicles is included as these make up nearly 40% of household vehicles today (Schipper et al., 2011).
- Buses, including intercity, school, and local transit services
- Passenger air travel within the US or Japan
- Passenger rail, including both local transit and intercity services
- Passenger ships or boats for Japan. For the US, these are negligible.

Freight transportation

- Trucks and trucking
- Freight rail
- Domestic freight ships or boats
- Domestic air freight

Fig. 1 gives the breakdown of per capita energy use for travel and freight in the two countries by mode. Fig. 1 shows that passenger cars and freight trucks, both in Japan and the U.S.A., comprise almost 85% of the CO_2 emission from transportation in the two countries. Thus, any significant improvement in CO_2 emissions in the transportation sector has to include improvements in efficiency and changes in usage of passenger cars and freight trucks. Japan's CO_2 emissions from the whole transportation sector

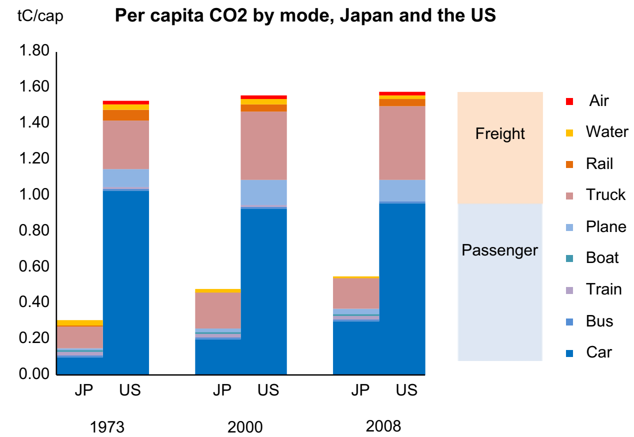

Fig. 1. Per capita CO_2 by mode, Japan and the US.

(passenger and freight) were about 244 $MtCO_2$ in 2008. About sixty percent of that came from passenger transportation and forty percent came from freight transportation.

In the subsequent analysis, we will focus on passenger transportation to disentangle the sources of CO_2 emissions. Comparison of Japan's freight emissions with other countries (including Korea) can be found in Kamakate and Schipper (2009) and Eom et al. (2011).

2.2. Analysis of passenger transportation patterns and trends in Japan

In this section, we will provide an analysis of CO_2 emissions and trends in passenger transportation in Japan. To provide comparative perspective, the trends will be compared with those in the United States. In this research, we will use an analytical framework based on Kiang and Schipper (1996) and developed more fully by Schipper et al. (2000), which consists of the components shown below:

A. Activity: volume of transportation measured in passenger-kilometers (pkm)

S. Structure: modal shares in total activity

C. Intensity: CO_2 emission per activity (pkm), which is the product of the energy intensity I times the CO_2 content of the fuel F. Since F is overwhelmingly dominated by oil (despite the important share of electric rail in travel), we keep I and F separated and focus primarily on I.

Then, CO_2 emission is calculated from the aggregation of CO_2 emissions in each mode calculated from the formula shown below.

$$CO_2\ emission\ (tCO_2) = G = \sum A \times S \times I \times F = \sum A \times S \times C.$$
$$total\ activity\ (\mathrm{pkm})\ \mathrm{X}\ structure(=mode)\ (\%)\mathrm{X}\ CO_2\ intensity\ (tCO_2/\mathrm{pkm}) \quad (1)$$

Each factor (activity, structure (mode), intensity) will be analyzed with respect to CO_2 emissions.

As Eq. (1) implies, energy use for travel is the product of total travel, the modal shares, and the energy intensities of each mode. Combing the energy intensity of each mode with the CO_2 intensity of each fuel (or electricity) gives the CO_2 intensities of travel, and for Eq. (1), total CO_2 emissions for travel.

2.3. Transport activity

Fig. 2 shows the per capita breakdown of travel activity from 1973 to 2008 in each country. Passenger travel per capita in the United States is about 2.5 times greater than in Japan. Historically,

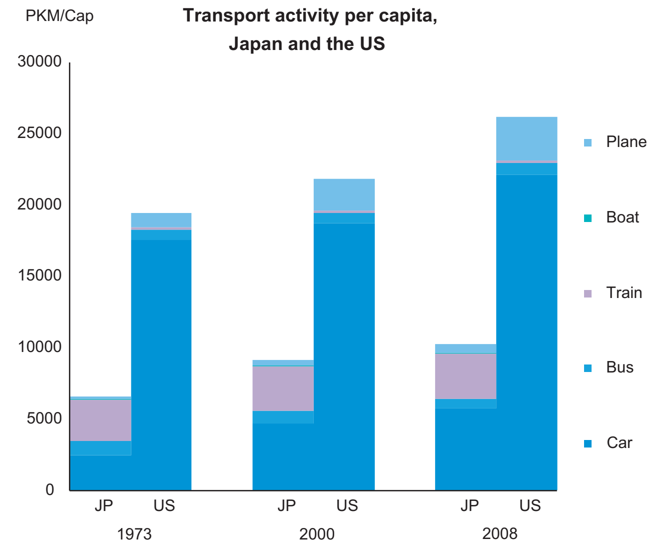

Fig. 2. Transport activity per capita, Japan and the US.

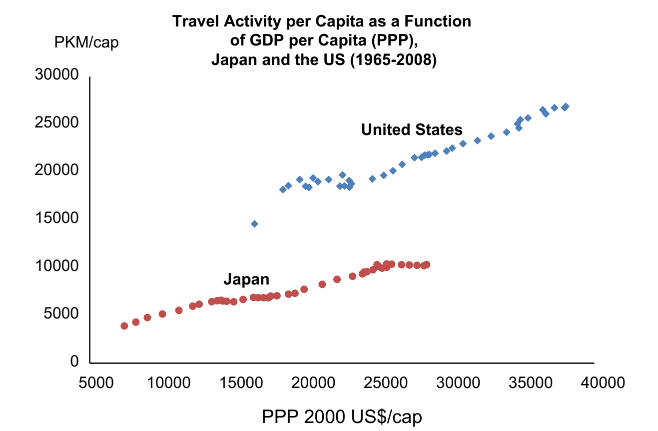

Fig. 3. Travel activity per capita as a function of GDP per capita (PPP), Japan and the US (1965–2008).

passenger activity (travel) per capita increased steadily in both the U.S. and Japan because of economic growth. With increases in population, the result was even greater growth in total travel. Controlling for population trends, in the U.S., pkm/capita increased by 1.1% per year from 1973 to 2008 while the pkm/capita in Japan increased by 1.4% per year. The difference in growth rate between the two arose because Japan started at a lower level than the US, and the share of automobile travel itself was much lower in the total. As we will see, the growth in Japan was driven principally by the subsequent growth in automobile ownership and use.

If we examine the increase in recent years, the growth in passenger activity per capita in Japan seems to have finally stopped and started to decrease in 2003. A similar plateau in the US and other countries is evident, even as GDP continued to grow (Millard-Ball and Schipper, 2011). However, in each country, travel has generally increased with GDP/capita, which raises the issue of whether that couple will be relaxed or even reversed as GDP continues to grow. Fig. 3 shows that the travel activity per unit of GDP in the U.S. is more than twice that in Japan. Uncovering the reasons behind this difference is crucial to understand whether either nation's level will stabilize or even decline. The most obvious difference is geography—Japan is more densely populated, with the major urban centers of Tokyo, Osaka, and Nagoya in close proximity to one another. Destinations are close in dense Japan than in the US, and traffic is slower, so the cost in time of a journey is higher. Some policy measures may also account for the difference, as we explain in subsequent sections.

2.4. *Structure (mode)*

The breakdown of passenger activity in Japan (Fig. 2) over time showed that the biggest contributor was cars, which accounted for 55.8% of all passenger activity in 2008. It is striking that the share of rail in Japanese passenger activity is 30.9%—very high compared to 0.6% in the U.S. and about 10% for major Western European countries. That of buses is also much higher in Japan than in the US—in fact, per capita travel for bus and rail in Japan come close to that of per capita air travel in the US! Both of these differences are consistent with what is observed around the world—denser countries have both lower total per capita travel and a higher share of that travel in collective ground modes. These tend to lose importance as income grows, but we can see Japan's collective level today is still well above that of even European countries (Millard-Ball and Schipper, 2011; Webster and Bly, 1981). Japanese move far less and less in cars than Americans (or Europeans).

As with other countries, the biggest increase in passenger activity in Japan over time came from cars. Cars excluding kei-cars increased from 235 billion pkm in 1975 to 559 billion pkm in 2008. Kei-cars increased from 28.0 billion pkm in 1975 to 216.2 billion pkm in 2008.[3] Airplane passenger activity in Japan increased rapidly from 19.1 billion pkm to 81.0 billion pkm in 2008. Although this represents 6.6% of total passenger activity, it is still less than half that of that in the U.S. and only about a third of the U.S. per capita value. If foreign travel were counted, however, Japan would doubtless close some of the gap with the U.S. Note that our U.S. figures include travel in the over 80% of light trucks and SUVs that were used as household vehicles in the 2000s, a figure that rose from under 30% (of a much smaller number) in the early 1970s (Schipper et al., 2011). It is ironic perhaps that while Japan's individual mobility has been boosted by small cars with an engine capacity under 660 cc, that of the US comes from vehicles with six times or more the engine capacity. We will discuss the policy measures that likely contributed to this difference in Section 4.

As for bus and rail, these were almost insignificant in the US and their shares or per capita values changed little from the 1970s to 2008. By contrast, the shares of bus travel in Japan fell sharply as car use grew, and the per capita values of bus travel in 2008 were lower than in 1975. Rail travel in 2008, however, was close to its peak of the early 1990s of over 3100 pass-km/capita. Examining the composition of rail travel, we find that travel on the *Shinkansen* increased cumulatively by 12.5% while travel on other forms of rail declined by 2.2% between the earlier peak in 1993 and 2008. Given the modest resurgence in rail travel, which nearly reached its early 1990s peak again in the late 2000s, we surmise that the *Shinkansen* both boosted rail travel and encouraged significant switching of air travelers to rail in competitive markets (Shibahara et al., 2011).

In summary, Japan's per capita travel and modal structure have evolved as expected over time as per capita GDP rose. Yet, they still differ significantly from those of the U.S. and Europe as marked by a significantly lower level of total domestic travel (well under one-half of the US per capita level), and a much lower

[3] Neither EDMC nor ML2 list passenger travel for kei-cars from before 1987. Following Kiang and Schipper (1996) we extrapolate travel to these previous years by the product of each year's kei-car distance driven times the average number of people per kei-car in 1987.

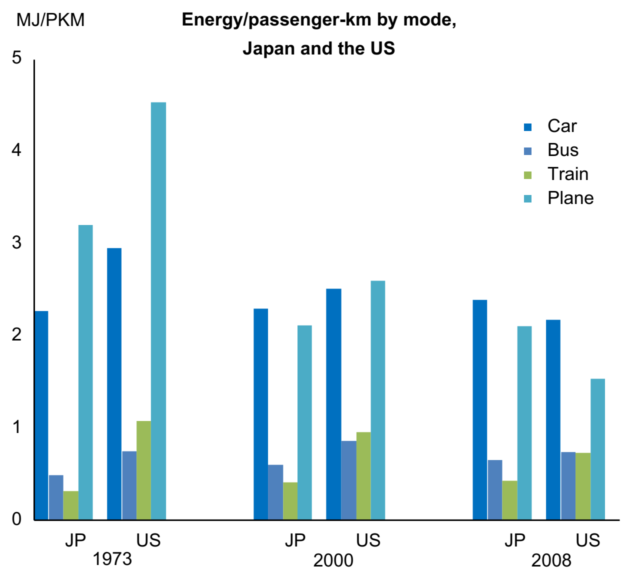

Fig. 4. Energy/passenger-km by mode, Japan and the US.

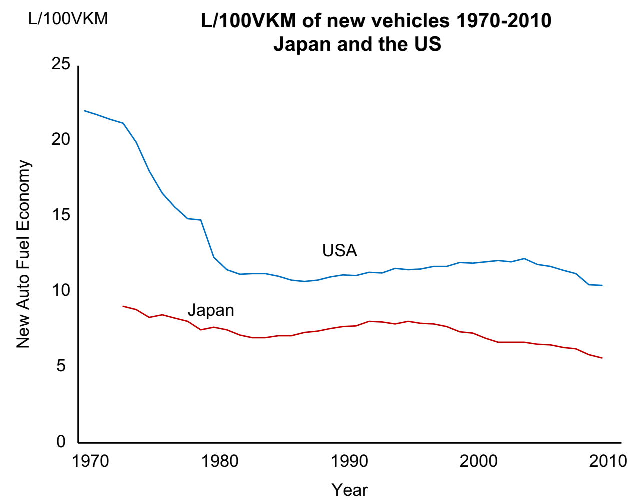

Fig. 5. L/100VKM of new vehicles 1970–2010 Japan and the US.
Note: because different test cycles are used in Japan and the US to characterize new auto fuel economy, caution should be exercised when directly comparing the absolute values in this figure.

share of car travel (less than 65% vs. typically 85% in Europe and 88% in the U.S.).

2.5. Energy intensity by mode

Energy intensity of car travel (including kei-cars) and air in Japan is around 2.0 MJ/pkm, that of Buses, at about 0.7 MJ/pkm, is less than half of them; and that of Rail (about 0.4 MJ/pkm calculated from primary energy; 0.2 MJ/pkm calculated from electricity kwh) is substantially lower than the others. The energy intensities of travel modes in Japan vary considerably in relation to the United States. As Fig. 4 shows, those of bus or rail travel are low, even including the primary energy required to make electricity for rail. On the other hand, the energy intensity of air and automobile travel was historically below levels in the U.S., but in recent years, this relationship has reversed. Consolidation and rationalization of the airline industry in the U.S. has improved passenger load factor from about 71% in 2000 to 80% in 2008 for domestic travel. The same figure for Japan has remained stagnant at about 65%. In 2008, the energy intensity of car travel in Japan was about 10% higher than that in the U.S.

It may seem surprising that car travel in the U.S. and Japan have nearly the same energy intensities. In terms of new auto fuel economy (Fig. 5)—measured on a standardized test cycle for the purposes of determining compliance with fuel economy standards—the Japanese fleet uses about 15% less fuel/km than that of the U.S. Japanese cars are considerably smaller and less powerful. However, the picture changes when we consider actual, on-road energy intensity (Fig. 6). Congested traffic appears to be the reason for the surprising near-equivalence of energy intensities. A stock-wide model of the Japanese fleet suggests these would obtain 6.2 l/100 km using the standard 15-mode test (IEE 2010). Raising this aggregate number by 33% to reflect real traffic gives a much closer fit to the on-road fleet fuel economy figures. For reference, the US EPA uses a corresponding adjustment of around 25% to raise tested vehicle fuel economy to what would be expected in real traffic. The prevalence of high speed rail travel in Japan may ironically contribute to lower on-road automobile energy intensity—as more driving is accounted for by city travel, which is generally less energy efficient than intercity travel by highway—and lower energy intensity of air travel—as airlines are forced to compete by offering high-frequency service between

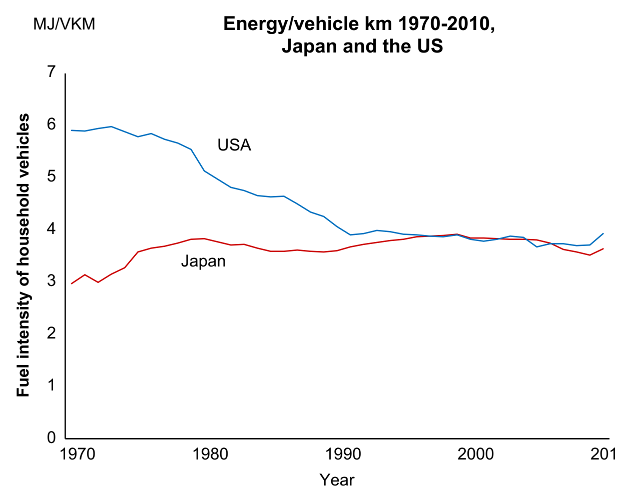

Fig. 6. Energy/vehicle km 1970–2010, Japan and the US.

urban areas, reducing load factor.[4] The fact that there are so many kei-cars in Japan, usually occupied by single-drivers, may further lower the average occupancy of cars and therefore raise average fuel use/passenger-km. In contrast, the low energy intensities of bus and rail travel in Japan can be attributed to high load factors, i.e., full vehicles.

The average car on the road in the US in 2010 used about 34% less fuel than one in 1973. Trends in the fuel intensity of new Japanese cars have been mixed. Between the mid 1980s and until late 1990s, consumers were favoring more luxury, sporty, powerful cars with more horsepower and torque. As a consequence, the share of the largest cars among new vehicles grew steadily, and with that growth, energy use per veh-km or pass-km for cars grew, raising energy intensities of aggregate transport until a peak in 2001/2, in contrast to a large sample of European countries or the US (Millard-Ball and Schipper, 2011). Aggregate intensity in the US, while much higher, fell slowly during the same period, as Fig. 6 shows.

The energy intensity of kei-cars increased 28% from 1.63 MJ/pkm in 1975 to 2.08 MJ/pkm in 2006. This can be attributed to changes

[4] We thank an anonymous reviewer for raising this point.

in regulation. The maximum displacement of kei-cars was raised from 550 cc to 660 cc in 1990, which resulted in greater demand for these vehicles as well as a change in the types of vehicles classified in this category. Immediately following the 1990 reform, kei-car activity and energy consumption increased rapidly. kei-car energy consumption increased more rapidly than activity after this reform, hence increasing energy intensity. We will return to the policy context surrounding kei-cars in Section 4.

2.6. Analysis

The absolute values of energy use in passenger transportation in Japan increased by 149% (3.6% increase per year on average) from 1.001 PJ in 1975 to 2.490 PJ in 2001. The decomposition of the factors in Eq. (1) shows that this was driven upward primarily by increased travel, driven in turn mostly by growth in car travel. However, after 2001, energy consumption decreased by about 9% to 2.267 PJ in 2008. The decline occurred both because of a flattening in total travel, most markedly of car use, as well as a decline in the energy intensity of car use.

The Japanese population increased by 14% from 1975 to 2008, while transportation energy consumption increased 126%. Thus, energy consumption per capita in Japan increased by 97% from 9.0 GJ/capita in 1975 to 17.7 GJ/capita in 2008, driven mostly by the increase for cars. This is quite different from the U.S., where almost no change was experienced because even as early as 1975, car ownership (in cars/1000) was almost as high as it was in Japan in 2008. Hence, this important driver of growth showed much less influence in the U.S.

Since oil products dominate the fuel mix, Japan's transportation CO_2 emissions follow a trend very similar to Japan's energy consumption. As a consequence of passenger activity, structure (mode) and CO_2 intensity, the CO_2 emission of passenger transportation in Japan increased 146% (3.5% increase per year on average) from 71 $MtCO_2$ in 1975 to a peak of 175 $MtCO_2$ in 2001, and decreased to 156 $MtCO_2$ in 2008. U.S. CO_2 emission per capita in 2006 was 4.31tCO_2/capita, which was about 3.5 times of that in Japan (1.24tCO_2/capita). Considering CO_2 emissions per GDP, in the U.S. it decreased 43% from 201 $kgCO_2$/GDP in 1975 to 114 kg CO_2/GDP in 2006, while in Japan it remained fairly constant (46 kg CO_2/GDP in 1975 and 45 kg CO_2/GDP in 2006). U.S. CO_2 intensity per GDP is still about 2.5 times of that in Japan but the gap has been narrowing over the thirty year period.

If all the factors in Eq. (1) are considered, the changes in Japans CO_2 emissions for travel can be summarized by a Laspeyres decomposition. Laspeyres indices decompose changes in passenger transport energy use into several underlying factors (Schipper et al., 1992). They allow us to evaluate the hypothetical impact of activity, modal structure, and modal energy intensity as if only each of those factors changed and the others were held constant at base year values. A more detailed overview of the methodology and applications to other contexts is available elsewhere (Ang and Zhang, 2000; Ang, 2005; Millard-Ball and Schipper, 2011).

Table 1 shows annual average changes by decade since 1970 for Japan. The "Actual" column represents the change in total energy use for passenger transportation. Transport energy use in Japan grew at a very high rate in the 1970s, averaging about 7.8%, but growth slowed down in subsequent decades and turned negative in 2000–2008. Japan is fairly exceptional in this regard—of six developed countries analyzed by Millard-Ball and Schipper (2011), the only other country to record a decline in passenger transport energy use in recent years is the United Kingdom.

The "Activity" column depicts the hypothetical case where modal structure and intensity are held to base year values, while total travel activity is allowed to change.[5] As Table 1 shows, transportation activity in Japan flattened out in recent years after three decades of consecutive growth. This may be due in part to demographics—Japan's population peaked in 2006 and has been essentially flat during the first decade of the 21st century.

Table 1
Laspeyres decomposition of passenger transport energy use in Japan.

	Actual (%)	Activity (%)	Structure (%)	Intensity (%)
1970–1980	7.8	2.6	1.7	3.1
1980–1990	2.7	3.4	1.1	−1.8
1990–2000	3.6	1.5	0.9	1.2
2000–2008	−0.9	−0.1	−0.3	−0.7

Note: Actual refers to the actual annual average change in energy use in Japan during the specified decade. Activity is the hypothetical annual average percentage change in energy use if only activity had varied, with modal structure and modal energy intensities held at 1990 levels. Structure is the hypothetical annual average percentage change in energy use if only modal structure varied, with activity and modal energy intensities held at 1990 levels; Intensity is the hypothetical annual average percentage change in energy use if only modal energy intensities varied, with activity and modal structure held at 1990 levels.

The "Structure" column shows the hypothetical case where the modal share of cars, bus, rail and air is allowed to change while holding activity and intensity constant.[6] Changes in mode share have not been a large contributor to changes in passenger energy use in most developed economies over the past several decades (Millard-Ball and Schipper, 2011). In this regard, Japan stands out somewhat—the shift away from public transportation, particularly rail, towards automobile transportation in the 1970s and 1980s increased transportation energy use, and in recent years, the share of bus and rail has begun to rise again, contributing to a decline in transportation energy use. A similar "U-shaped" trend in the use of public modes can also be observed in other developed countries such as the United States, France, and the United Kingdom. However, this pattern had the largest impact on energy use in Japan, where public modes account for a much larger percentage of overall transportation.

The "Intensity" column shows the case where modal intensities are allowed to change while holding activity and structure constant.[7] The figure shows that there have been important swings in the energy intensity of travel in Japan over the past four decades. Intensity grew during the 1970s and 1990s but fell in the 1980s and 2000s. This likely reflects policy responses undertaken after the oil shocks of the 1970s and the Kyoto Protocol. As discussed earlier, the energy intensity of car use in Japan increased in the 1990s due to consumer preferences and tax changes favoring larger automobiles. Overall, this mixed pattern

[5] Formally, we calculate energy use E^A as a percentage of total energy use in the base year as follows: $E^A = A_{it}/A_{io}$. A_{it} is total activity for country i in year t and A_{io} is total activity in the base year. We then calculate annual average change according to the following formula: $\partial^A_{a,b} = \exp\frac{\log E^A_{ib} - \log E^A_{ia}}{b-a} - 1$, where $\partial^A_{a,b}$ is the average change for the country between years a and b.

[6] Formally, we calculate the following formula, where E^S is energy use analogous to E^A in the prior footnote: $E^S_{it} = A_{i0}\frac{\sum_m S_{mit} I_{mi0}}{E_{i0}}$ where S_{mit} is the share of each mode m in country i in year t, I_{mt0} is the energy intensity for each mode in country i in the base year, and E_{t0} is total energy use in the base year for country i. Annual average changes are calculated in the same way we calculated $\partial^A_{a,b}$ in the previous footnote.

[7] Formally, we calculate:

$$E^I_{it} = A_{i0}\frac{\sum_m S_{mit} I_{mi0}}{E_{i0}},$$

where I_{mit} is the energy intensity for each mode m in time t for country i, A_{mt0} is the activity of each mode m in the base year for country i, and E_{t0} is total energy use in the base year for country i. Annual average changes are calculated in the same way we calculated $\partial^A_{a,b}$ in the footnotes above.

has meant that energy intensity of travel in Japan has been roughly flat during the past four decades, unlike other major economies, where there has been a downward trend (Millard-Ball and Schipper, 2011).

3. Japanese government policy measures related to transportation efficiency

This section focuses on the political and policymaking context for Japanese passenger travel. Perspectives on the U.S. can be found in Schipper (2009) and Morrow et al. (2010). A more historical overview of Japan's transportation sector energy policies is available in Hayashi (2001), MLIT (2002), Furukawa (2007, 2008, 2009), and Lipscy (2011, 2012). The Japanese government has generally viewed energy efficiency as a high priority since the oil shocks of the 1970s, which revealed the vulnerability of the economy to energy supply disruptions. In more recent years, energy efficiency has been promoted as an important mechanism to achieve CO_2 emissions reductions to address global warming. In the transportation sector, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has been primarily responsible for developing efficiency policies in coordination with the Ministry of Economy, Trade, and Industry (METI) and the Ministry of the Environment.

3.1. Fuel economy and top runner

A primary focus of Japanese efficiency policy in the transportation sector is automobile fuel economy standards. MLIT officials justifiably see reduction of emissions from cars as critical for reducing CO_2 emissions in the transportation sector. Increasing fuel economy is viewed as a high priority. Cross-nationally, Japan adopted fuel economy standards relatively early, in 1979. In comparison, the E.U. only adopted fuel economy standards in 2005 and made them mandatory in 2008, and although U.S. CAFE standards have been in place for a comparable period, they have consistently mandated a lower fleet-average fuel economy level (An and Sauer, 2004).

A notable Japanese innovation in recent years is the "Top-Runner" program. Top Runner was introduced under the Law Concerning the Rational Use of Energy in 1998. According to the law, machinery and equipment are included in the Top Runner program when three criteria are met: 1. The product is used on a mass scale in Japan; 2. The product consumes a considerable amount of energy for its operation; 3. There is considerable room for improvement in the energy efficiency of the product (Agency for Natural Resources and Energy, 2010). Automobile fuel economy has been included in the program since its inception in 1998. In addition, 23 products ranging from air conditioners to electric toilet seats are currently included in the program.

The Top Runner program is designed to automate improvements in efficiency by setting target improvements based on the product with the highest energy efficiency level currently on the market. The highest-performance product is then used to set average energy performance standards several years into the future.[8] In 2004, a detailed labeling standard was implemented to inform consumers about the efficiency of a particular product against the standard (IEEJ 2007). The program has several advantages over existing regulatory approaches such as minimum and average energy performance standards. First, because efficiency targets are set using existing products in the market, the targets are inherently realistic and feasible. Second, the standards are unlikely to be too lax as they are continuously updated based on products with the best performance. Third, the program reduces the need for lengthy negotiations with industry and the scope for industry lobbying. Because standards are based strictly on the most efficient technologies available, there is relatively less room for lobbying to weaken standards or carve out advantages that benefit specific firms. Japanese bureaucrats indicate that the program is generally implemented in an automatic, incremental manner and without a great deal of political interference.

However, Japan's implementation of Top Runner is not without its critics. Under current regulations, passenger automobiles are divided by fuel type and sixteen weight classes, with targets determined within each category according to the most efficient product currently available on the market (Agency for Natural Resources and Energy, 2010). This emphasis on targets within vehicle weight classes has been a feature of the Japanese approach since 1979. Critics have pointed out that this approach discourages efficiency improvements through weight reduction. Furthermore, according to current proposals, Japan's fuel economy standards will slip behind the EU by 2020, and China and the United States will catch up considerably by 2025 (The International Council on Clean Transportation, 2011).

Japan has traditionally placed considerable emphasis on regulatory policies for the purpose of achieving energy efficiency improvements. Japan's regulatory approach may be particularly suited to its political economic institutions, which are characterized by close consultation between bureaucratic officials and private sector actors (Samuels, 1987; Okimoto, 1990). Compared to more legalistic, arms-length political systems, this means that regulations are less likely to be unrealistic or accompanied by inadvertent consequences. In addition, Japanese policymakers operate in an environment where cooperation from producers is relatively easy to secure. Unlike the United States, where the domestic auto industry generally lobbies aggressively against tough fuel economy standards, major players like Toyota and Honda tend to be relatively supportive of Japanese regulations due to their expertise in energy efficient models. Detailed regulations implemented primarily in consultation with domestic automobile producers—such as the division of automobiles into a large number of weight classes—can also function as a nontariff barrier against foreign competitors.[9]

3.2. Keijidosha

Automobile fuel efficiency in Japan has also been facilitated by policy measures to promote *keijidosha*, or light-weight automobiles. As we noted above, Kei-cars are defined by restrictions on engine displacement and car size and are subject to a variety of incentives, such as lower taxes, lower insurance costs, and relaxed registration requirements. These measures are summarized in Table 2.

The kei-car program was initially implemented in Japan immediately after World War II as a means to advance motorization. However, the program has continued and expanded even after Japan became one of the largest automobile markets in the world. Kei-cars, because they are generally lighter and smaller than regular cars, tend to be more energy efficient: in 2006, 0.15 kg CO_2/pkm compared to 0.19 kg CO_2/pkm for regular automobiles. For this reason, even after motorization was achieved, Japanese government officials have continued to promote kei-cars to facilitate automobile fuel efficiency and reduce CO_2 emissions

[8] A more detailed overview is available at the website of the Agency for Natural Resources and Energy, Japan: http://www.enecho.meti.go.jp/policy/saveenergy/save03.htm [accessed 19.07.12].

[9] Japanese government officials generally deny that this is a primary motivation for the regulations.

Table 2
Subsidies for Keijidosha in Japan.

	Kei-Cars	Regular automobiles
Automobile acquisition tax	3%	5%
Automobile weight tax	3800 yen per vehicle	5000 yen per 0.5 tons
Automobile tax (Keijidosha Tax)	7200 yen	29,500 yen
Highway discount	20% (rural areas)	0%
Compulsory automobile liability insurance	13,600 yen	15,110 yen
Registration of parking space	Not necessary (rural areas)	Required

Note: Taxes are annualized—the weight tax is collected every three years. Automobile tax for regular automobiles is based on lowest displacement category (< 1.0L).

However, energy efficiency is only one goal of the kei-car program. Kei-car subsidies are politically popular, particularly in rural areas where public transportation is limited and households often purchase a kei-car as a second vehicle. Surveys of kei-car ownership find disproportionately high shares of ownership among rural residents, housewives, and the elderly (Ozeki, 2009). Ownership rates exceed 50% in rural prefectures such as Kochi, Nagasaki, Shimane, and Okinawa, while the figure is only 23% for Tokyo. In effect, the kei-car program is a rural subsidy, but one that is designed to promote energy efficiency in the countryside, where public transportation service is limited. This is underscored by the fact that several incentives associated with kei-cars are only available in rural areas, most importantly the waiver on requirement to register a parking space and a discount on highway tolls (Lipscy, 2012). Kei-car subsidies also benefit commercial enterprises and small business owners, who are intensive users of the cars.

In recent years, there has been some tension between the political and efficiency goals of kei-car subsidies. To accommodate kei-car users and producers, the qualifications for kei-car status have been gradually relaxed over time. In the 1950s, an automobile could qualify as a kei-car only if engine displacement was below 360 cc. In 1976, larger, more powerful automobiles were classified as kei-cars (length < 3.2 m, width < 1.4 m, height < 2.0 m, engine displacement < 550 cc). After additional changes to regulations in 1990, 1998, and 2000, kei-cars are now considerably more powerful and larger than their predecessors (length < 3.4 m, width < 1.48 m, height < 2.0 m, engine displacement < 660 cc).

This gradual relaxation of the regulations concerning kei-cars has led to criticism that there is no longer any meaningful difference between the largest kei-cars and regular, compact automobiles.[10] The Japanese government has considered rationalizing kei-car subsidies in recent years as part of its plans to reduce taxation on energy efficient (eco) cars, with initial proposals calling for an elimination of kei-car subsidies.[11] However, strong resistance from beneficiaries has led to maintenance of the status quo. Kei-car subsidies have also become an important sticking point with the United States in Japan's negotiations to join the Trans-Pacific Partnership (TPP), a proposed free trade agreement.[12]

[10] See, for example, Inomoto Koichiro, "'Mobility Giron' Mushi Shita Kankyo Jidoshazei [Environmental Tax Ignores 'Mobility Debate']," *Response*, [17.09.10].

[11] "Kankyo Jidoshazei, Keijidosha wa 4baikyo no Zozei ni [Environmental Automobile Tax: Keijidosha to face taxation greater than four times current levels]," *Response*, [16.09.10].

[12] E.g., "'Kei' Kikaku, Bei Share Ni Eikyo Sezu [The 'Kei' Regulation Does Not Affect US Share]" *Asahi Shinbun*, [18.01.12].

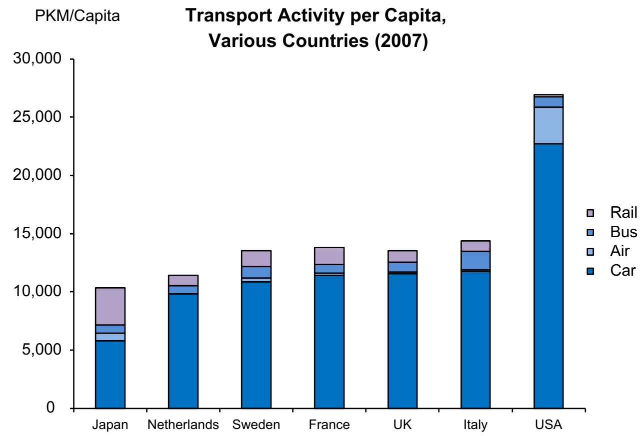

Fig. 7. Transport activity per capita, various countries (2007).

3.3. Eco-car tax breaks

Japan implemented "eco-car" tax breaks and subsidies in April 2009 as part of a stimulus package in response to the global financial crisis. The policy was intended to support the domestic automobile industry during the global downturn, while also encouraging the purchase of energy efficient vehicles. The tax incentive offers a 50–100% reduction in the automobile weight tax and automobile acquisition tax for energy efficient vehicles, with particularly generous treatment given to electric cars, natural gas vehicles, plug-in hybrids, and clean diesel vehicles.[13] In addition, a direct subsidy program was implemented, offering cash incentives for the purchase of energy efficient vehicles. However, funding for the subsidy program in 2009 and 2012 were quickly exhausted. The tax breaks were originally designed as a short-term measure, but they were subsequently extended for an additional three years in 2012. The incentives likely contributed to the 11% increase in regular automobile (i.e., non-kei) sales in 2010—the first increase in sales since 2003.

3.4. Transport activity and mode share

As we discussed earlier, the primary factors that differentiate Japan cross-nationally are not energy intensity by mode, but rather transport activity and mode share. This is illustrated clearly in Fig. 7, which includes comparisons with several OECD countries in 2007. On average, Japanese travel less in aggregate and are also more likely to travel by rail rather than car. Several Japanese policy measures have likely contributed this outcome. We focus in particular on measures that have made automobile transportation and ownership expensive in Japan. Like kei-car subsidies, these measures were implemented in part to facilitate energy efficiency, but they also reflect a political, redistributive rationale.

Taxes related to automobile ownership in Japan have been historically high compared to other countries (Table 3). Automobile ownership is subject to a variety of taxes, most importantly a 5% acquisition tax, an automobile tax assessed yearly, and a vehicle weight tax assessed every three years. The weight tax is assessed during *shaken*, a government-mandated automobile inspection program that owners must submit to every one, two, or three years depending on the vehicle type. Automobile owners are also required to register a parking space, which discourages vehicle

[13] Details are available at the MLIT website: http://www.mlit.go.jp/jidosha/jidosha_fr1_000028.html [accessed 22.05.12].

Table 3
Automobile taxation (2002).
Source: Japan Automobile Manufacturers Association.

	Japan	UK	France	Germany	USA
Tax per automobile (US $)	$5800	$4700	$3750	$3300	$1500

Note: Assumes ownership for 9 years of a vehicle with the following characteristics: 1800 cc, 1100 kg, purchase price of 1.8 million yen.

Table 4
Highway tolls (2002).
Source: Japan Public Highway Corporation.

	Japan	France	Italy	USA	UK	Germany
Toll highways as a % of total	100%	74.8%	86.2%	8.9%	0%	0%
Average toll (US $/km)	$0.21	$0.07	$0.05	n/a	n/a	n/a*

* Germany started imposing a toll on trucks only equivalent to $0.12/km in 2005.

ownership in urban areas such as Tokyo and Osaka, where land is scarce and expensive.

Japanese gasoline tax rates, though higher than the United States, do not stand out according to international comparisons. Japan's gasoline taxes averaged about 80% of the OECD average rate in 1980, but have recently fallen to about 60–70%.[14] Japanese transportation officials defend these relatively low rates on the grounds that the burden of taxes falls disproportionately on low income citizens, and comparable results may be achievable through regulatory means.

Compared to other countries, Japan has maintained unusually high tolls on highway usage. Table 4 provides one cross-country comparison, based on data from 2002 (recent experimentation with toll reductions will be discussed below). When Japan completed its first highway, the *Meishin Expressway* in 1958, tolls were levied with the specific purpose of paying off the World Bank loan used towards its construction (Japan Automobile Manufacturers Association, 2006). According to these initial plans, Japan's major highway routes, connecting the metropolitan areas of Tokyo, Nagoya, and Osaka, should have become free of tolls by the early 1990s. However, during the oil shocks of the 1970s, LDP Prime Minister Tanaka Kakuei implemented a policy of pooling highway tolls in order to support construction of infrastructure in rural areas (Sugimoto, 2004). Instead of being eliminated, tolls on urban and inter-urban routes were repeatedly raised, imposing an onerous cost on highway travel. For example, highway travel from Tokyo to Osaka, about a 510 km (315 mile) trip, costs 13,500 yen, or $180.[15]

These various measures, which impose high costs on the Japanese automobile user, were sustainable because the revenues were generally directed towards powerful political supporters of the long-ruling LDP—in particular, rural residents and the construction industry. Political institutions in Japan—an electoral system that gave outsized influence to narrow interest groups over the general public, a strong bureaucracy, and one-party rule—made these arrangements durable (Lipscy, 2012). Revenues from the automobile acquisition tax, weight tax, and gasoline tax were allocated directly to rural areas or into the Road Improvement Special Account, where expenditures were earmarked for road construction and maintenance. Generous funds were also channeled towards quasi-public corporations that served as employment destinations for retired bureaucrats (a practice known as *amakudari*). Although these measures reduced incentives to use energy-inefficient automobile transportation, the accompanying redistributive policies became increasingly wasteful and unpopular (Inose, 2008).

Promotion of rail travel has also been an important objective of Japanese transportation policy. The motivation for this has varied considerably over time. From the Meiji Restoration through World War II, rapid construction of rail infrastructure was pursued as part of Japan's attempts to achieve rapid modernization and industrialization. The use of rail transportation for military purposes was accorded high priority (Sugino, 1970). After World War II, rail transportation was again promoted as a means to develop infrastructure and advance rapid economic development. Expansion of the rail network has also been promoted by politicians as a means to reward local constituencies with construction employment and better infrastructure. Particularly notorious was the prioritized construction of the *Joetsu Shinkansen*, which connected Tokyo to sparsely-populated Niigata, home prefecture of powerful LDP politician Tanaka Kakuei.

The vast Japanese *shinkansen* bullet train network predates concerns about energy efficiency, but in recent years, extension of the network has been justified as a measure to shift passenger volume from less efficient air and automobile travel. Expansion of the *shinkansen* is not motivated primarily as a CO_2 reductions measure—there are political considerations such as the interests of the construction and rail industries and the overall goal of expanding the transportation network. However, CO_2 reductions are an important externality and justification for further expansion.

3.5. Recent policy context in Japan

An important consideration for efficiency measures in the Japanese transportation sector has been compatibility with the support base or core constituency of the LDP—e.g. rural residents, the transportation industry, and the construction industry. In recent years, because of several important political changes, Japanese transportation efficiency policy has entered a new, more uncertain period. First, electoral reform in 1994 replaced the old system based on a single nontransferable vote (SNTV) with a mixed system placing greater emphasis on plurality voting in single-member districts. This has shifted the electoral strategy of politicians away from narrow appeal to interest groups—e.g. the construction industry—towards broader appeal to the median voter (Cox et al., 1999; Rosenbluth et al., 2010; Lipscy and Scheiner, 2012). Second, the Democratic Party of Japan (DPJ), which has a more urban support base, emerged as a serious competitor to the LDP and took over control of the government in 2009. Third, there has been a public backlash against perceived corruption and wastefulness in the transportation sector, which has led to various reforms designed to overhaul traditional arrangements (Inose, 2008).

These changes have introduced considerable uncertainty for Japanese energy efficiency policy. One illustration is the status of gasoline taxes and highway tolls. Revenue from these sources has been historically earmarked for road construction. These policies were designed to serve a dual purpose: the taxes and tolls contributed to energy efficiency by raising the cost of automobile fuel consumption, while also benefiting important political supporters of the LDP. As a minority party, the DPJ sought popular appeal by portraying these measures as wasteful giveaways, and it made elimination of gasoline taxes and highway tolls a core campaign platform. At the same time, with a relatively urban support base, the DPJ has advocated for pro-environmental policies, including significant reductions in CO_2 emissions. This put the DPJ in the awkward position as it ascended to power. In

[14] Calculated based on prices for regular unleaded gasoline (US$/Litre in PPP). Data from the International Energy Agency.

[15] As of 2011, assuming weekday travel and standard fare, which was typical historically. We will discuss recent discount policies in the following subsection.

2008, the gasoline tax briefly expired due to a political showdown as the DPJ-controlled upper house refused to approve an extension. Upon taking power in 2009, the DPJ gradually moderated its stance, choosing to eliminate tolls only selectively and backtracking on elimination of the gasoline tax. Elimination of highway tolls was suspended indefinitely after the March 11, 2011 Tohoku Earthquake in order to raise revenues for reconstruction. However, these traditional policies, which raise the costs of transportation for a large segment of Japan's population, have become more difficult to sustain under the incentives created by Japan's new electoral system (Lipscy, 2011)—Japanese politicians can no longer win elections by narrowly targeting pork to a small segment of the population.

Japanese policymakers also point out that they are confronting the challenges of diminishing returns—since Japanese energy efficiency in the transportation sector is already relatively high, incremental improvements are more expensive or impractical compared to other countries. One illustration is a recent initiative by MLIT to shift commercial freight from trucks to railroad. MLIT officials indicate that this has proved challenging for several reasons. First, because Japan has already achieved high capacity utilization on existing rail tracks, particularly in urban areas such as Tokyo and Osaka, there is little spare capacity open for commercial use. Trucks are seen as more convenient by most commercial users, particularly smaller businesses. Second, in Japan, passengers are prioritized over commercial traffic on rail. This is because of high passenger volumes and relatively little idle capacity on the rail network, particularly in metropolitan areas. Commercial trains therefore need to move in between passenger trains. This poses some difficulties—e.g. in urban areas, there is no idle capacity during peak hours in the morning and evening, so commercial trains must stop. This is not just an issue in final destinations such as Tokyo and Osaka. Between Tokyo and Osaka, trains must pass through several urban areas, which adds further delays. There are also concerns about the effect of heavy freight on the rails used for passenger transportation. Third, because land is scarce in Japan and population densities in urban areas are very high—partly as a result of existing policies that prioritized mass transit and made long-distance commutes from suburbs expensive—it is expensive and time consuming to expand the capacity of the rail network. As a practical matter, these factors make a shift from truck to rail freight in Japan in the near future unrealistic.

Japan will likely continue to pursue improvement of automobile fuel economy through regulation and tax incentives, as this remains a high priority among government officials. However, policies to achieve meaningful improvement of energy efficiency in other areas face problems. One of the DPJ's signature initiatives was a new CO_2 tax, implemented beginning in 2011 over a three year period. However, due to concerns about the burden of higher taxes, the tax is designed to only have a limited impact. The CO_2 tax is being implemented to effectively replace the gasoline tax. However, gasoline prices are projected to rise only by about 0.76 yen per liter (about 3 cents per gallon), and the expected reduction in CO_2 emissions associated with the tax is only about 1% by 2020 (Mainichi, 2010). Officials indicate that there is no clear political constituency for a CO_2 tax in Japan, save the Ministry of Finance, which sees the tax as a potential revenue source. Surveys indicate that public support for the tax is limited, ranging between about 25% and 40% in recent years (Japanese Cabinet Office, 2005, 2007).

3.6. Non-policy factors

Although we have focused on Japanese policy measures in the transportation sector, it is also worth acknowledging several non-

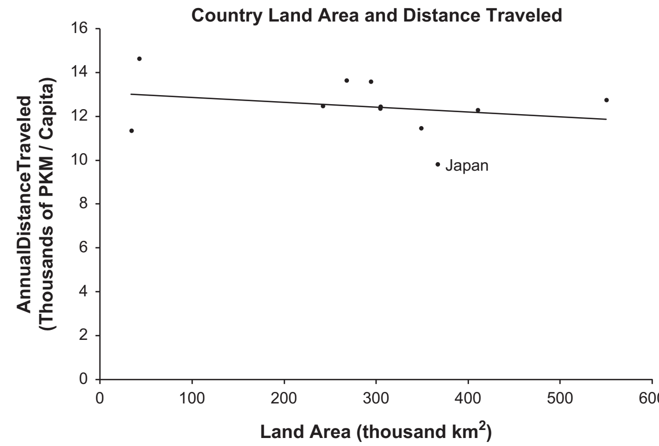

Fig. 8. Country land area and distance traveled.

policy factors that affect Japan's relative energy efficiency. In this subsection, we focus particularly on two non-policy factors that likely contribute to Japan's transportation trends—geography and urban population density.

Japan is a relatively small country with major urban areas in close proximity to one another. This likely encourages shorter overall travel distances and travel by rail. When comparing the relationship between travel distances and land area cross-nationally, country size appears to be a plausible explanation for why citizens in continental countries such as Australia, Canada, and the United States travel greater distances than smaller countries such as Japan. However, among relatively smaller countries, the relationship is considerably weaker. As Fig. 8 illustrates, among small, economically developed countries,[16] there is no clear relationship between land area and travel distances, and Japanese travel less than peers in much smaller countries such as the Netherlands.

Another plausible factor is high population density, particularly in urban areas, which increases the feasibility of mass transit. It is difficult to separate urban population density from the effects of transportation policy—an important reason why Japanese do not live in disbursed, distant suburbs is because automobile commutes into major urban areas are expensive and impractical because of the policy measures outlined above. Nonetheless, it is worth examining whether urban population density fully accounts for Japanese transportation trends. Fig. 9 plots urban population density, measured as the average of the three largest metropolitan areas in a country, against the rail and bus share of total distance traveled.[17] As the figure shows, rail and bus share tends to increase with greater urban population density. However, Japan's share is high even when accounting for its relatively densely populated urban centers.

We also considered a range of other proxies for geography and population density as well as relative economic development and demographics (65+ share of population). The results were much the same—Japan is an outlier in terms of travel activity and mode share. This suggests that Japanese transportation trends are not explained by non-policy factors alone.

[16] The countries included are France, Sweden, Japan, Germany, Finland, Norway, Italy, New Zealand, the United Kingdom, Denmark, and the Netherlands. Data are for 1995, the most recent year for which data is available for all of these countries.

[17] Data is obtained from Demographia, "Demographia World Urban Areas (World Agglomerations)." Countries included in the chart are: Canada, Australia, United States, France, Sweden, Japan, Germany, Finland, Norway, Italy, New Zealand, the United Kingdom, Denmark, and the Netherlands. Data is for 1995, the most recent year for which data is available for all of these countries.

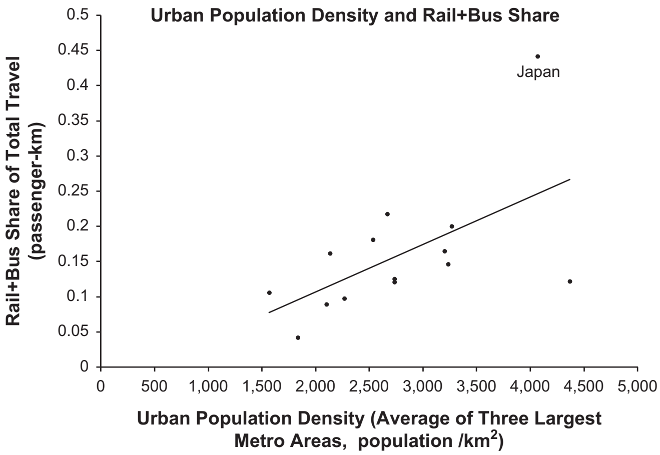

Fig. 9. Urban population density and rail+bus share.

4. Conclusion

Our analysis shows that the primary differences between Japan and the United States—as well as other countries—are low total per capital domestic travel and low automobile share. Another positive factor in Japan is low energy intensities of bus and rail travel, attributable to high load factors. Perhaps counter-intuitively, Japan does not differ significantly from the U.S. in terms of the energy intensity of automobiles. Despite superior fuel economy, realized energy intensity of cars in Japan is about comparable to those in the U.S. It is also striking that, while the energy intensity of U.S. passenger automobiles have improved continuously over the past three decades, Japan showed no improvement, albeit from a low base.

One irony, therefore, is that policy measures often highlighted by Japanese policymakers and foreign observers, such as the top-runner program, are not the main source of Japan's low energy use for transportation. Insofar as policies mattered, pork-barrel politics probably played a much larger role. After the oil shocks of the 1970s, the Japanese government raised various taxes and fees that made automobile travel expensive. The LDP, Japan's dominant political party at the time, redistributed the revenues to political supporters, primarily rural residents and the construction industry. Various automobile taxes and expensive highway tolls have made bus and rail travel highly competitive in comparison. Subsidies for kei-cars rewarded rural residents, who tend to be heavy users, while also improving the energy efficiency of rural transportation. These political arrangements have come under challenge in recent years, raising questions about the sustainability of Japan's traditional approach towards transportation sector energy efficiency.

Our results show that, contrary to the predictions of Kiang and Schipper (1996), Japan's transportation sector has not converged towards the structure of systems in other industrialized countries. Despite economic development on par with the West, Japanese continue to travel shorter distances and are less likely to travel by car. Some of this difference is surely due to factors such as geography and urbanization, but we have also raised several policy measures that likely contributed to this outcome: high highway tolls, high overall taxes on automobiles, and aggressive promotion of rail as an alternative to air and automobile transportation. More research is necessary to understand just how much of this difference is due to policy measures. Some recent policy changes, such as the temporary suspension of gasoline taxes in 2008 and various changes to highway tolls implemented in 2008–2011, offer opportunities to examine this issue in greater detail.

In the long-term, some trends in Japan will likely have a beneficial impact on energy efficiency and CO_2 emissions. The first is demographics—as Japan's population ages and shrinks, the country will require less energy for transportation and other activities. Continuing urbanization will facilitate greater use of energy efficient public transportation. It is also commonly reported that "*kuruma banare* (moving away from cars)" is becoming common among Japanese youth, and this is consistent with government surveys, which indicate a sharp decline in automobile ownership among Japanese below the age of 40 (Ministry of Internal Affairs and Communications, 2010). These factors, largely unrelated to efficiency policy, may move Japan towards greater energy efficiency and lower CO_2 emissions.

References

Agency for Natural Resources and Energy, 2010. Top Runner Kijun: Sekai Saiko No Sho Energy Kiki No Soshutsu Ni Mukete. METI, Tokyo.

An, Feng, Sauer, Amanda, 2004. Comparison of Passenger Vehicle Fuel Economy and GHG Emission Standards Around the World. Pew Center on Global Climate Change, Arlington, VA.

Ang, B.W., 2005. The LMDI approach to decomposition analysis: a practical guide. Energy Policy 33, 867–871.

Ang, B.W., Zhang, F.Q., 2000. A survey of index decomposition analysis in energy and environmental studies. Energy 25, 1149–1176.

Cox, Gary, Rosenbluth, Frances McCall, Thies, Michael, 1999. Electoral reform and the fate of factions: the case of Japan's LDP. British Journal of Political Science 29, 33–56.

Furukawa, Kotaro, 2007. Jidosha Kanren Zeisei no Genjo to Kadai [Current Situation and Issues Related to Automobile-related Taxation] ."Reference (August), pp. 5–99.

Furukawa, Kotaro, 2008. Doro Tokutei Zaigen no Ippan Zaigen Ka [Transfer of the Road Improvement Special Account to the General Account Budget]." National Diet Library Issue Brief (619).

Furukawa, Kotaro, 2009. "Kosoku Doro no Tsuko Ryokin Seido: Rekishi to Genjo [Regulations Concerning Highway Tolls: History and Present Situation]." Reference (October), pp. 99–118.

Hayashi, Yoshitsugu, 2001. Jidosha Kotsu Kanren Zeisei no Greenka: Oubeinichi ni Okeru Rekishiteki Haikei, Rironteki Kento to Koka Suikei. Kokusai Kotsu Anzen Gakkaishi 26 (3), 156–163.

Inose, Naoki, 2008. Doro No Kecchaku. Bunshu Bunko, Tokyo, Japan.

Jiyong, Eom, Lee, Schipper, Lou, Thompson, 2011. We Keep on Truckin: Trends in Freight Energy Use and Carbon Emissions in 10 IEA Countries. Summer Study Proceedings.

Japan Automobile Manufacturers Association, 2006. Japan's Auto Industry. JAMA, Tokyo.

Japanese Cabinet Office, Chikyu OndankaTaisaku ni Kansuru Yoron Chosa, 2005, 2007.

Kamakate, Fatumata, Schipper, Lee, 2009. Trends in truck freight energy use and carbon emissions in selected OECD countries from 1973 to 2005. Energy Policy 37 (10), 3743–3751.

Kiang, Nancy, Schipper, Lee, 1996. Energy trends in the Japanese transportation sector. Transport Policy 3 (1), 21–35.

Lipscy, Phillip Y., 2011. Efficiency Clientelism. Paper Presented at the Princeton Conference on Environmental Politics, Princeton, N.J.

Lipscy, Phillip Y., 2012. A casualty of political transformation? The politics of Japanese energy efficiency in the transportation sector. Journal of East Asian Studies 12 (3), 409–439.

Lipscy, Phillip Y., Scheiner, Ethan, 2012. Japan under the DPJ: the paradox of political change without policy change. Journal of East Asian Studies 12 (3), 311–322.

11 Nendo Zeisei Kaisei, Mainichi Shinbun, 17.12.10.

Millard-Ball, Adam, Schipper, Lee, 2011. Are we reaching peak travel? Trends in passenger transport in eight industrialized countries. Transport Reviews 31, 3.

Ministry of Land Infrastructure Transport and Tourism (Japan), 2002. Doro Seibi Taikei no Arikata [Considering the System of Road Maintenance]. In Report of the Council for Decentralization Reform, Tokyo.

Ministry of Internal Affairs and Communications, Zenkoku Shohi Jittai Chosa, 2010.

Morrow, W., Ross, Kelly Sims, Gallagher, Gustavo, Collantes, Lee, Henry, 2010. Analysis of policies to reduce oil consumption and greenhouse-gas emissions from the US transportation sector. Energy Policy 38 (3), 1305–1320.

Okimoto, Daniel I., 1990. Between MITI and the Market: Japanese Industrial Policy for High Technology. Stanford University Press, Stanford.

Ozeki, Kazuo, 2009. Keijidosha no Rekishi wo Furikaeru. JAMAGAZINE February.

Rosenbluth, Frances McCall, Thies, Michael F., 2010. Japan Transformed: Political Change and Economic Restructuring. Princeton University Press, Princeton.

Samuels, Richard J., 1987. The Business of the Japanese State: Energy Markets in Comparative and Historical Perspective. Cornell University Press, Ithaca.

Schipper, Lee, 2009. Automobile Fuel; Economy and CO_2 Emissions in Industrialized Countries: Troubling Trends through 2005/6. EMBARQ, Washington D.C.

Schipper, Lee, Marie-Lilliu, C, 1999. Carbon-Dioxide Emissions from Transport in IEA Countries: Recent Lessons and Long-Term Challenges. International Energy Agency, Paris, France.
Schipper, Lee, Marie-Lilliu, C., Gorham, R., 2000. Flexing the Link Between Transport and Greenhouse Gas Emissions. International Energy Agency, Paris.
Schipper, Lee, Saenger, Calanit, Sudardshan, Anant, 2011. Transport and carbon emissions in the United States: the long view. Energies 4 (4), 563–581.
Schipper, Lee, Scholl, Lynn, Price, Lynn, 1997. Energy use and carbon emissions from freight in 10 industrialized countries: an analysis of trends from 1973 to 1992. Transportation Research Part D 2 (1), 57–76.
Schipper, Lee, Steiner, Ruth, Duerr, Peter, An, Feng, Strom, Steinar, 1992. Energy use in passenger transport in OECD countries: changes since 1970. Transportation 19 (1), 25–42.
Shibahara, Naoki, Kato, Hirokazu, Hayashi, Yoshitsugu, 2011. A methodology for identifying lower carbon transportation systems for inter-regional passengers: rail vs. aviation. 12th WCTR, Lisbon, Portugal.
Sugimoto, Yuzo, 2004. Kosoku Doro no Seisaku Cost to Zaiseito Yushi Seido Kaikaku [The Policy Cost of Highways and Reform of FILP], vol. 29. Kaikei Kensa Kenkyu Tokyo, Japan. [pp. 99–114].
Sugino, Kuniaki, 1970. Nihon Ni Okeru Tetsudo Seisaku No Tenkai [The Development of Railroad Policy in Japan], vol. 19. Ritsumeikan Keizaigaku, Tokyo, Japan. [p. 2].
The International Council on Clean Transportation, 2011. ICCT Comments on Japan's Draft PV Fuel-Economy Standards. Washington, D.C.
U.S. Department of Energy, 2010. Transportation Energy Data Book. Washington, D.C.
Webster, F.V., Bly, P.H., 1981. The demand for public transport. Transport Reviews 1 (4), 323–351.