Transportation Research Part D 27 (2014) 51–58

Contents lists available at ScienceDirect

Transportation Research Part D

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

Innovation, the diesel engine and vehicle markets: Evidence from OECD engine patents

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ARTICLE INFO

Keywords:
Corporate R&D performance
Economics of innovation
Fuel efficiency
Vehicle engines

ABSTRACT

This paper uses a patent data set to identify factors fostering innovation of diesel engines between 1974 and 2010 in the OECD region. The propensity of engine producers to innovate grew by 1.9 standard deviations after the expansion of the car market, by 0.7 standard deviations following a shift in the EU fuel economy standard, and by 0.23 standard deviations. The propensity to develop emissions control techniques was positively influenced by pollution control laws introduced in Japan, in the US, and in the EU, but not with the expansion of the car market. Furthermore, a decline in loan rates stimulated the propensity to develop emissions control techniques, which were simultaneously crowded out by increases in publicly-funded transport research and development. Innovation activities in engine efficiency are explained by market size, loan rates and by (Organisation for Economic Cooperation and Development) diesel prices, inclusive of taxes. Price effects on innovation, outweigh that of the US corporate average fuel economy standards. Innovation is also positively influenced by past transport research and development.

1. Introduction

The paper identifies the historical factors that influence firm innovation of diesel engines, with a focus on the EU, Japan and US markets in 1974–2010. Despite vast research on innovation, the relationships among environmental policy, publicly-funded transport research and development (R&D) investment and patents, are not well known. Diesel engine innovation is closely linked to the car, truck and bus markets in Japan, the US, the EU and China.[1] A major benefit of rapid innovation is that the costs of climate policy for the transport sector can be lower than costs in the absence of innovation. Innovation can turn public RD, for energy efficient engines, into a cost effective investment.

2. Background

An innovation is defined by Freeman and Soete (1997) as the means of matching technical options to market opportunities through activities including experimental development and design, trial production and marketing. An innovation can be

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[1] Amongst OECD countries, the fraction of diesel fuel in transport fuels, excluding rail and water, was 14% in 1973 rising to 34% in 2010 (International Energy Agency, 2010) and growing at nearly four times the rate of gasoline consumption. In China, diesel accounts for 60% of fuel used in transport.

http://dx.doi.org/10.1016/j.trd.2013.12.012
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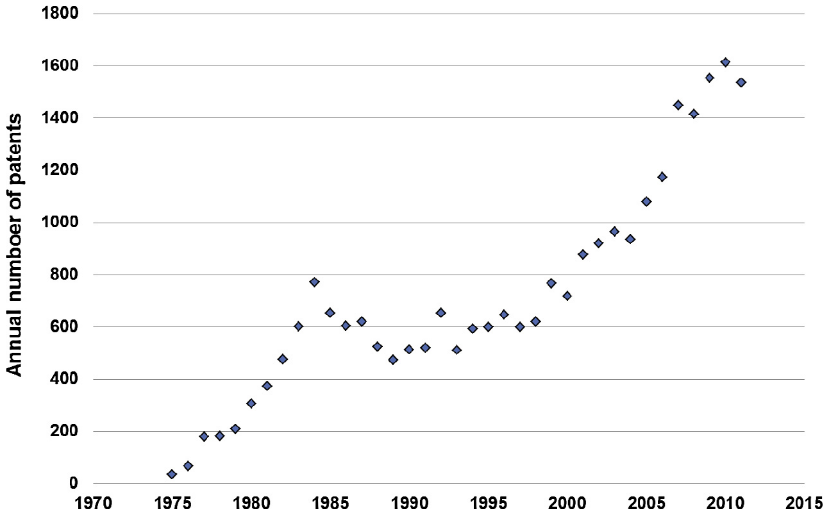

Fig. 1. Diesel engine patent counts: US, Japan, EU and rest of the world. *Note*: Annual number of patents by date of publication. *Source*: European Patent Office (2012).

either product or process related. In the transport context, because diesel engine technology is associated with poor air quality and with non-CO_2 emissions, improvements in pollution technology have been sought. The European Commission (EC) (2008) introduced the Air Quality Directive. In addition, diesel engines emit considerable amounts of CO_2 (Bonilla, 2009), resulting in continued efforts to improve fuel efficiency. Fig. 1 uses patent data to show technological changes of the diesel engine between 1974 and 2010.

Despite the continued rise in patent registrations (setting aside the hybrid diesel) there have been no radical innovations in vehicle engines for 50 years. There have been waves of incremental innovations and we focus on these in the context of environmental laws, air pollution standards and engine efficiency standards, based on the premise that these act as incentives for firms to find new, and cheaper, methods of reducing pollution (Porter, 1991). Our patent dataset covers these main diesel engine categories and considers diesel engine design and air pollution control innovation in Japan, US, and the EU.

We examined 26,378 patents registered between 1974 and 2010, most of which originate from independent inventors, car firms and components firms based in Japan, the EU and the US.[2] Independent variables include measures of energy prices, three measures of market size, one metric of public R&D expenditure, three metrics of NOx emissions limits, and two of vehicle fuel efficiency standards. The year of vehicle sales is lagged by two periods over 1978–2008. Three models are used. One tests whether the propensity to innovate responds to oil prices, to public R&D expenditure, to standards of diesel engine efficiency, and more crucially to market size factors. The second tests if the propensity to innovate increases after the introduction of air quality laws in key Organisation for Economic Cooperation and Development (OECD) countries. The third considers factors explaining the growth of innovation in diesel engine efficiency.

Non-CO_2 pollution standards are temporally correlated to both growth in patents and to the number of patent categories (Fig. 2). Policy also has had a role. Besides the EC standard of 2008, non-CO_2 pollution standards were introduced in the 1980s and 1990s, by the US, Japan, and the EU, with the latter being the least strict in part because it has a large diesel car stock. The timing of pollution standards was vital to raise the level of innovation of the diesel engine. These pollution standards are also linked to innovations that control exhaust gas emissions, mainly NOx.[3]

Our analysis has its foundation in a number of prior studies, including those by the Organisation for Economic Cooperation and Development (2011), of patents between 1965 and 2009. This analysis found that fuel taxes play the largest role in diesel engine innovation, but omitted the effects of public and private R&D funding. The US Environmental Protection Agency (2013) reports that many innovations in fuel injection and variable valve timing are major factors in fuel efficiency; fuel injection systems having replaced carburetors 20 years previously. These technologies are now being replaced by the direct injection system, particularly, in gasoline engines. Many studies find evidence that actions by public policy makers on non-CO_2 and on CO_2 emissions controls raise the innovation effort of firms (Organisation for Economic Cooperation and Development, 2011; Hascic et al., 2009).

Difficulties arise with these and similar studies in that they rely on aggregate data on energy-related innovations, and that they make no distinction between national markets i.e. car sales, cost of capital, or the effects of public R&D. We adopt a more disaggregate approach.

[2] The data are grouped by 'diesel engine' categories and include innovations in diesel engine design, air pollution control.

[3] Japan's NOx standard was introduced in 1974; the US NOx limits set in 1976; and the Euro NOx limit for diesel in 2000 (Hascic et al., 2009). The first US non-CO_2 standards, set in 1980, covered HC and the NOx diesel emissions and led to significant increases in innovations. The US Clean Air Act of 1990 also led to rapid innovation in pollution control. A series of pollution controls introduced in the EU (Euro III) had a similar effect (Lutsey, 2012).