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The Role of Policy Instruments on the Pattern of Diffusion: The Case of Solar Photovoltaic in Asia Pacific

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Abstract

While an increasing number of literature investigates the role of policy instruments on the renewable energy technologies (RETs) investment, the effect of policy instruments on the pattern of diffusion on RETs remain understudied. Therefore, this paper explores the effectiveness of the policy instruments on the pattern of diffusion of solar PV capacity for a set of 6 Asia Pacific countries from 2000 to 2015. The present study is different from previous literature by exploring the effect of policy inducement namely subsidies and tax incentives on the pattern of diffusion of solar PV. The analysis is performed by estimating a diffusion of innovation equation using a pooled OLS model. Results indicate the behaviour of previous adopter and policy intervention does reflect individuals' tendency to switch to the PV technology. In detail, the existence of tax incentives promotes the shift of solar PV capacity during the analysis period. By exploring the effect of policy inducement on the pattern of diffusion, there is a potential for the current policy to be introduced at the states level to facilitate the diffusion of solar PV.

Keywords: Bass diffusion, renewable energy policy, renewable energy technology diffusion, tax incentive, subsidy, solar energy

1. Introduction

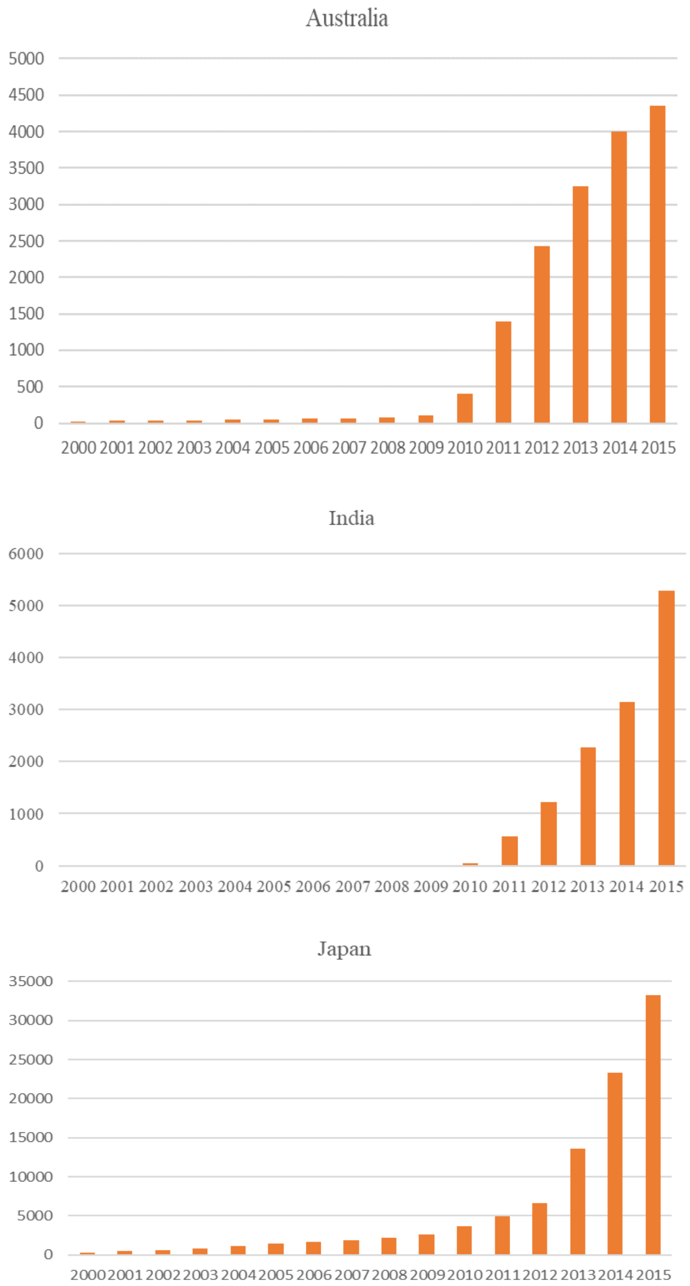
Most of countries has renewable energy sources (RES) targets and policy interventions in place (REN21, 2016). Such deployment policies, i.e. the desired diffusion of RES into the market via remuneration such as subsidies and tax incentives can be effective tools in creating a market pull which fosters the uptake of renewables. Recently, the design characteristics of the policy incentives and the regulatory uncertainty surrounding the incentives have drawn increasing interest from researchers with numerous literatures concentrating on measuring the competitiveness of the policy schemes on the performance of RES investment (Groba & Breitschopf, 2013; Ritzenhofen & Spinler, 2016; Romano, Scandurra, Carfora, & Fodor, 2017; Zhixin & Xin, 2011). While an increasing number of studies investigate specific designed features of policy incentives on the RES incentives, however, limited research is available to measure the effect of policy intervention on the pattern of diffusion on RETs (Davies & Diaz-Rainey, 2011; Radomes & Arango, 2015). Therefore, this paper aims to explore the effect of policy incentives namely subsidy and tax incentives on the pattern of diffusion of RES capacity based on Bass diffusion of innovation model (Bass, 1969) in the context of Asia Pacific countries.

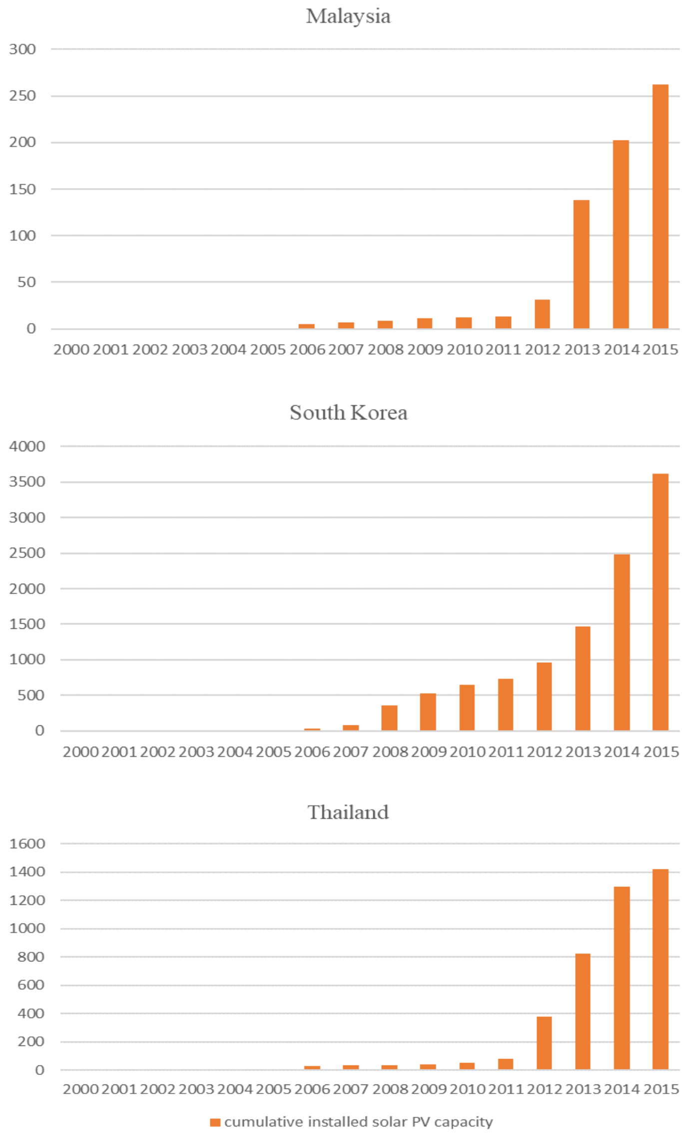
1.1 Electricity overview and solar photovoltaic (PV) development in Asia Pacific countries

Asia Pacific is a diverse region, it has the world's ten populous countries and has almost 60 per cent of world's population (IRENA, 2013). At present, a vast majority of electricity generated is derived mainly from coal, where its demand will spike nearly 53 per cent between 2010 and 2035 (DLA PIPER, 2010). Nevertheless, the region has less than three percent of global oil resources and eight percent of global gas resources (Estrada, Park, & Ramayandi, 2010). The Asia Pacific cumulative installed capacity from renewable energy sources (excluding hydropower) is expected to reach 535.2 gigawatt GW by 2020 (Global Data, 2016). Of all the renewable energy resources, solar energy is relatively abundant in most of the region, with solar PV installed capacity stood at 63.3 GW in 2014 (IRENA, 2013).

During 2000-2015, solar PV installed capacity in some of Asia Pacific region has developed rapidly and unevenly (refer to Figure 1). Japan leads other Asia Pacific countries for the biggest solar PV installation since 2000 with its cumulative installed capacity stood at 33,000 Mw in 2015. South Korea ranks behind Japan with its installed capacity stood at 3,615 Mw in the end of 2015. While Japan solar photovoltaic has been expanding since early 2000s, other countries (South Korea, India, Australia, Malaysia and Thailand) started adopting the technology at rapid pace in recent years.

Figure 1: Solar PV cumulative added capacity installation in Asia Pacific, in Megawatt (Mw) from period 2000-2015





Source: International Renewable Energy Agency (IRENA, 2015)

2.0 Renewable energy technology modelling diffusion

Since its appearance in 1969, the Bass model has been applied for a wide variety of real-world problems for the theory of diffusion of innovation such as forecasting (Chu & Pan, 2008; Tseng & Hu, 2009), new product growth (Cheng, 2012; Chiang & Wong, 2011; Kaldasch, 2011), and innovation diffusion (Cho & Koo, 2012; Meade & Islam, 2006; Peres et al. 2010). Previous studies in RETs diffusion include PV system adoption in Tennessee's poultry industry (Bazen & Brown, 2009), India (Peter et al. 2006), and the United States and Japan under the lenses of an innovation value-added chain framework (Shum & Watanabe, 2009).

Watanabe et al. (2000) finds the "Sunshine Project" policy initiative had resulted in more R&D on PV systems, which in turn raised solar cell production and lowered prices. Furthermore, they used patent data on companies manufacturing PV systems to measure cross-sectoral technology spill overs, which they demonstrated had a positive effect on PV. They contended that PV systems benefit from positive interactions among R&D stock, market growth, and lower prices, and predicted that these interactions will result in further proliferation of PV systems. In another study, Wustenhagen and Bilharz (2006) reviews the impact of government policies on the renewable energy market and identified the reasons for the adoption of PV systems in Germany. They pointed out that while renewable energy demand has increased every year, the industry has not been able to achieve volume production so far. They identified the implementation of FIT and other policies as the primary driver of PV system diffusion in Germany.

In addition, RET diffusion studies based on Bass diffusion include forecasting cross-country PV adoption pattern by Guidolin and Mortarino (2010) for 11 countries. The study found that government policy incentives is significant in promoting PV diffusion. However, the study does not emphasis the specific policy design on the pattern of PV diffusion throughout the sample period. Next, Diaz-Rainey (2011) considers induced diffusion as an intervention that aims to alter the speed and/or the total level of adoption of an innovation by directly or indirectly internalizing positive and/or negative externalities on 25 OECD countries. The study reveals that influence of policy stimuli, such as green energy incentives, drives a faster rate of early adoption and subsequently sustains the imitation process, and is external because is determined outside the population of innovators and imitators. Meanwhile, Radomes & Santiago (2015) investigates the support schemes in Medellin, Colombia on the pattern of PV diffusion from 2000-2014. In the study, cost-benefit analysis is applies to compare policy options by measuring their financial impacts, total net benefits, net present value of benefits and costs. The study reveals that both subsidy and FIT is important in stimulating the diffusion of photovoltaic system for the state. Nevertheless, the study does not include the characteristics of FIT policy itself for example; contract duration, digression rate as to indicate the heterogeneity policy on the effect of PV diffusion.

The results of prior research indicate that policy intervention have a positive impact on the diffusion of PV systems. However, there is limited research available that systematically examine the effect of the market-based policy namely subsidy and tax incentives on the adoption of PV system based on Bass diffusion model. Therefore, the present study intends to fill the gap in the previous literature by specifically explore the effect of policy interventions; subsidy and tax incentives on the pattern of Bass diffusion model of solar PV. Finally, this study is different from the previous literature by exploring the policy inducement effect on the pattern of photovoltaic diffusion in the context of Asia Pacific, a diverse region which has less than three percent of global oil resources and eight percent of global gas resources (Estrada et al., 2010).

3.0 Methodology

According to Bass (1969), the development over time of a new product's growth, is a result of the purchase decisions of a given set of adopters. These purchase decisions are assumed to be influenced by two sources of information: an external one, like mass media and advertising, and an internal one, namely social interactions and word-of-mouth. Davies and Rainey (2011) adds that policy can play an important role in process innovations. The governmental policy interventions share some of the key features of marketing of durables: they are exogenous to the mechanisms of imitation. Hence, the basic Bass model that modified by Davies and Rainey (2011) can be written as:

$$\boldsymbol{D_{t+1} - D_t = [a + bD_t].[1 - D_t]} \qquad (1)$$

Based on Equation 1, the diffusion $\boldsymbol{D_t}$ is considered as the proportion of PV system deployed capacity (in MW) with respect to the total installed capacity from all forms of electricity generation. Thus, the increase in solar PV usage (capacity) during period t to t+1 depends on the previous adoption level, and the extent of generation who not yet using solar PV technology. Building on the formulation of Davies and Diaz-Rainey (2011), this study adds further variables in order to disentangle policy-driven effects from the basic innovation coefficient. The pooled OLS regression model specification is:

$$\boldsymbol{S_{it} = a_i + b_1 D_{it} + b_2 subsidy_{it} + b_3 tax_{it} + b_4 GDP_{it} + b_5 educ_{it} + b_6 peak_{it} + \mu_i} \qquad (2)$$

Equation (2) states the successive increase in the photovoltaic adoption capacity in year t depends on the diffusion process that already in progress ($\boldsymbol{D}$), on the introduction of capital subsidy ($\boldsymbol{subsidy}$), on the presence of tax incentives by the policymakers ($\boldsymbol{tax}$), on the status of the income ($\boldsymbol{GDP}$), on the status of the education ($\boldsymbol{educ}$) and on the status of the maximum electricity demand ($\boldsymbol{peak}$) of coal power. $\boldsymbol{\mu_i}$ is the error term.

3. 1 Data and description of variables

This study uses unbalanced panel data from selected Asia Pacific countries, namely; Australia, India, Japan, South Korea, Malaysia and Thailand over the time period of 2000-2015. In addition, the policy enacted in Australia and India are vary across the regions, thus this research also captures regional policy enactment in Australia and India to be implemented in the analysis. The regions for Australia are Western Australia, New South Wales, Australian Capital Territory, Victoria and Queensland. Meanwhile, the regions for India are Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh.

3.1.1 Data on photovoltaic penetration

The level of diffusion for solar PV is measured by:

$$D_{it} = \frac{MW\ installed\ solar\ PV\ capacity\ in\ country\ or\ state\ i\ in\ year\ t}{total\ MW\ installed\ capacity\ from\ all\ forms\ of\ generation\ country\ or\ state\ i\ in\ year\ t} \quad (3)$$

Data on the solar PV installed capacity (MW) is obtained mostly on International Renewable Energy Agency (IRENA, 2015). Meanwhile, data on solar PV installed capacity for regional area i.e. Australia and India are retrieved from Indian Ministry of Renewable Energy (MNRE, 2015) and Australian Energy Regulator (AER, 2015). These two websites provide annual reports that extensively capture the trend of PV for each state. Next, data on the total MW installed capacity from all forms of generation is individually obtained from electricity operator annual reports; i.e. Korea Electric Power Cooperation (KEPCO, 2015), Tenaga Nasional Berhad (TNB, 2015), Kansai Electric Power Company (KEPCO, 2015), Hokkaido Electric Power Company (HEPCO, 2015) and Electricity Generating Authority Thailand (EGAT, 2015).

This study accounts subsidies and tax incentives to determine the effect on the solar PV uptake level across the Asia Pacific. Most of the subsidies and tax incentives data are obtained mostly from IEA's renewable policy database (IEA, 2015), and cross-checked with government websites as well as other related energy publications. The availability of tax incentives and subsidies are decoded as dummy variable, taking value as 1 to indicate the presence of the policy design for the particular year, and 0 otherwise.

Next, income is measured by gross domestic product (GDP) constant USD 2005 prices (in logarithm). The income for the countries is applied to control for the possibility that wealthier country will have greater percentage of solar PV development (Carley, 2009; Dong, 2012). In addition, previous literature indicate that level of education is positively associated with the likelihood of the PV uptake (Balta-Ozkan, Yildirim, & Connor, 2015; Rai & Sigrin, 2013). As such, this study includes government expenditure on education, total (percentage of GDP) to account for the effect of pattern of PV diffusion. Besides, this study applies maximum demand of power output (MW) (in logarithm) to indicate proxy for demand shocks of both domestic and export consumption (Zhang, 2013). All the conditioning variables are retrieved from the World Bank database (Worldbank, 2015) and countries' department of statistics including Australian Bureau of Statistics (ABS, 2015), Indiastat (Indiastat, 2015), Statistics Bureau of Japan (stat.go,2015), Statistics Korea (Kostat, 2015) and National Statistical Office of Thailand (NSO, 2015). The descriptive statistics for all variables are presented in Table 2.

Table 1: Summary of descriptive statistics of variables

	Observation	Mean	Std. dev	Min	Max
Solar PV uptake	304	0.005	0139814	-0.03	0.094
Diffusion level	304	0.017	0.039	0	0.225
Subsidies	304	0.23	.46	0	1
Tax incentives	304	0.29	0.46	0	1
Log of electricity maximum demand (MW)	304	19826.69	37726.12	555.13	182689
Log Gross domestic product (USD constant)	304	4.34	1.26	0	5.99
Education level (government expenditure on education,% of GDP)	304	8.74	5.79	1.93	22.3

4.0 Preliminary analysis

Based on Table 3, the result of pooled OLS reveals that existing level of diffusion is significant in fostering the shift of solar PV capacity. In specific, 1 per cent increase in the existing of penetration level stimulates the shift of solar PV by 0.288 percentage point on average per year. For the policy enactment, it is reveals only tax incentives are important in fostering the uptake of the PV technology. In detail for a 10-unit increase in tax incentives, the diffusion pattern of solar PV will increase by 8 percentage point. However, the effect of subsidy on the deployment of solar PV is not significant during the period of study. In addition, the result from the control variables show that income is necessary for facilitating uptake of photovoltaic for the countries.

In addition, the regression is also tested with robustness check. The result of Wooldridge (2002) test p-value more than 10 per cent significant level reveals that the regression is not suffering from serial correlation problem. Next, the result from the Breusch-Pagan (1979) test of p-value more than 10 per cent significant level also reveals that the regression does not suffering from heteroskedasticity problem.

Table 2: Pooled ordinary least square (OLS) regression results

Dependent variable: successive increase of solar PV	
Independent variables	
Intercept a_i	-0.045 (0.039)
Diffusion level D_i	0.284*** (0.026)
Tax relief	0.007*** (0.003)
Subsidy	0.001 (0.002)
Log peak demand for coal power	-0.002 (0.005)
Log income	0.002** (0.001)
Education	0.002 (0.006)
R-square overall	0.546
R-square adjusted	0.474
Breusch-Pagan	0.12
Wooldridge	0.11
No. Observation	304
F-statistics	7.67***

Note: The values in parentheses are standard errors. * indicates significance at 10 per cent. ** significance at 5 per cent, *** significance at 1 per cent.

4.1 Discussion

The result of the analysis confirms the role of diffusion level is important in motivating the shift of PV technology capacity for the countries. Based on the policy inducement effect, the findings show the policy incentive has driven the uptake of solar PV in Asia Pacific. This finding is consistent with the literature that effective energy support policies are necessary to catalyse the diffusion process until renewable energy technologies can compete with the conventional sources (Keyuraphan, Thanarak, Ketjoy, & Rakwichian, 2012). A supportive tax policy reduce the costs and risks of renewable energy investments by lowering the upfront investment costs (Sawin et al. 2004). This study finds that subsidies does not help to stimulate the diffusion pattern of the photovoltaic during the analysed period Apart from that, the analysis suggests that income plays a positive impact on solar PV uptake. This finding is consistent with Rode and Weber (2012) and Sardianou and Genoudi (2013) where household wealth is often cited as being determinants in PV system. Next, although not significant, the inverse relationship between peak demands of conventional electricity suggests that conventional energy is still needed in order to cater the society's needs for the context of Asia Pacific. In addition, since the solar PV is operating in small scales, thus it does not sufficient to cater the electricity demand for the society. Lastly, level of education does not affecting the diffusion pattern for the solar PV. This is maybe true that societies does not need to acquire a certain level of awareness about the technology (Romano et al. 2017).

Conclusion and limitation

Drawing on the Bass (1969) and Davies models of innovation diffusion (2011), this paper develops several assumptions that suggest the patterns of diffusion are different when policy plays an important role in the diffusion process. In specific, this paper explores the effectiveness of the renewable energy policy instruments on the pattern of diffusion of solar photovoltaic capacity for a set of 6 Asia Pacific countries from 2000 to 2015. The present study is different from previous literature by exploring the effect of policy inducement namely; subsidy and tax incentives on the pattern of diffusion on solar photovoltaic uptake. It has found that countries will follow a Bass curve when there is a strong policy incentive occur. Besides that, the existence of tax incentives also promotes the shift of solar photovoltaic capacity throughout the analysis period.

The present study presents a limitation that must be noted. First, low coefficient for the policy variables for the regression analysis suggest the renewable energy for most countries has been deployed in great amount in more advance countries (i.e. Japan, South Korea and Australia) and recently in middle income countries (Malaysia, India and Thailand), and the enactment of the policy are just been implemented recently for most countries. Therefore, future research could carefully examine the effects of policy schemes by including European countries in the analysis, where the enactment of the policy schemes has been implemented since year 1990 (Jenner et al. 2013).

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