Trends and Volatility in Ecological Patenting in the USA

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Abstract: The paper analyses the trends in ecological patenting in the US market from 1975 to 1997. Ecological patents have been increasing steadily in number over time. Germany contributed more than 10% of the total number of US environmental patents and is by far the strongest foreign performer. The time-varying nature of the volatility of environmental patents registered in the USA is examined using monthly data from January 1975 to December 1997. The asymmetric AR(1)-GJR(1,1) model is found to be suitable for modelling the number of ecological patents registered in the USA.

***Keywords*:** Ecological patents; Trends; Volatility; GARCH; GJR; Asymmetry

1. INTRODUCTION

Ecological problems such as global warming, ozone layer depletion, land erosion, depletion of natural resources and acid rain have drawn the attention of politicians and researchers globally to the challenge of ecologically sustainable development. Since the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, the business community has established the International Business Council for Sustainable Development to promote technologies that are less harmful to the environment. They have also developed the voluntary environmental standards ISO 14000 to establish continually improving processes for environmentally responsible behaviour. There has also been a higher level of research and development (R&D) investment channelled into research that is related to the natural environment.

The patent system is a firmly entrenched component of the economic and industrial environment in which technologies and trade links are developed. Since the mid-1970s, patenting has become a powerful intellectual property protection mechanism for which there is an economic market. It is held by many that patents are conducive to economic growth. If it is accepted that the institution of patenting is essential to co-ordinate market forces, it would be expected that the efforts of the international business community to deal with environmental problems will result in more ecological innovations being patented. A number of studies have confirmed that patenting activities cause immediate and subsequent market changes [see, for example, Soete, 1987; Griliches et al., 1991; and Ernst, 1995 and 1997]. International patenting has also been found to be a significant determinant in productivity performance [Fagerberg, 1987]. Thus, the greater the number of environmental patents, the more likely will the market economies be to adopt a course of sustainability.

With its large and technologically advanced markets, the US economy has always been highly favourable to companies and individuals interested in protecting their intellectual rights. The USA has also been very attractive to foreign residents who have been willing to establish their innovation priority. There was an unprecedented surge in patenting activities in the USA by foreign countries from the mid-1980s onward [Kortum and Lerner, 1999; Arundel and Kabla, 1998]. In absolute numbers, the US patent office receives by far the largest number of foreign applications [Archibugi, 1992], and overall is the largest source of information on technological developments. Amendola et al. [1998] claim that patents granted in the USA are particularly suited for the investigation of the impact of technological change on trade performance at the sectoral level. Of interest for this paper are technologies related to the environment.

This paper analyses trends in the development of more environmentally-friendly technologies, or technologies which assist in abating existing ecological problems. Data from the US Patent and Trademark Office (PTO) for the period 1975 to 1997 are used to analyse whether there are signs of a technological paradigm shift in relation to the ecology.

The plan of the paper is as follows. Section 2 describes the data used in the analysis. General trends in environmental patenting are discussed in Section 3. Section 4 briefly discusses the GARCH and GJR models. This is followed by an analysis of volatility in environmental patenting in Section 5. Some concluding remarks are given in Section 6.

2. DATA DESCRIPTION

Empirical information on patent data is collected from the US PTO, through its on-line search engine (http://164.195.100.11/netahtml/search-adv.htm). The time series data used consist of monthly observations for the number of environmental patents with application dates between 1975 and 1997. The data were extracted in April 2001. It was decided to use the time series of parents according to application date to avoid artificial distortion of the data caused by organisational delays in the process of granting patents.

The current US patent classification system does not provide special categories which cover environmental patents. Consequently, the following approach was used to identify such patents: a patent is considered to be related to the ecological environment if its abstract or full text contains words such as "ecology", "ecological", "ecologically" (or any other word beginning with "eco"[1]) or "environmentally". It was impossible to incorporate in this definition of environmental patents a keyword search using "environment" or "environmental" because of their widespread use outside the area of ecological environment, such as in the digital, physical or economic environments. Individual reading and checking of each of the thousands of American patents containing "environment" or "environmental" would have been an excessively time- and labour-intensive exercise. It was felt to be highly unlikely that a patent related to ecologically sustainable technology would not include one or more of the various definitional words given above. In addition, the same approach was used consistently across the time series, which makes it possible for trends and patterns in the data to be analysed.

[1] The word "eco" was excluded because it generated only patents referring to the so-called Eco enzyme, which is somewhat outside the area of this study.

3. GENERAL TRENDS IN ENVIRONMENTAL PATENTING

Figure 1 shows the trends in environmental patenting in the USA, based on monthly data from January 1975 to December 1997. It is clear that the trend is upward sloping, in general, with the 1990's being a period of intensive patenting of technologies which are related positively to the environment.

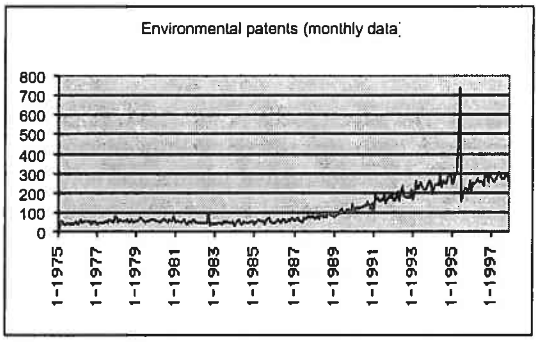

Figure 1: US Patents Related to the Ecological Environment by Date of Application, 1975(1) – 1997(12)

The total number of patents registered in the USA during the same period has also been increasing steadily (see Figure 2), reaching a peak of close to 170,000 approved patents from the applications lodged in 1997. Figure 2 shows the trends in issued patents by date of application, which is a more accurate measure of patent activity than the date of issue (as it is not influenced by administrative delays in the US Patent and Trademark Office related to the processing of the applications[2]). In addition, the figure shows the trend in approved environmental patents, which reached 3,300 in 1997.

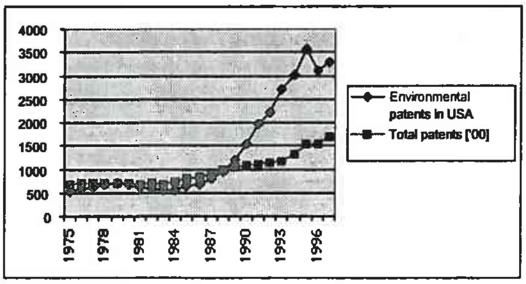

Figure 2: Total US and Environmental Patents by Date of Application, 1975(1) – 1997(12)

[2] It takes an average of two years for a patent application to be approved. However, in some cases it can take much longer, and delays of 7-8 years are not unknown. It is likely that the number of approved applications in more recent years will have increased.

A comparison of the two trends shows that the number of US environmental patents lodged has been growing at a faster rate than the total number of US patents, which is a positive development. This relationship indicates changes in the world economy resulting in greater interest in the natural environment. Technological innovators seem to have responded to community concerns in relation to the technologies used as well as their impact on the environment.

Though increasing, the share of patents which address ecological issues and their implications remains very small (see Figure 3). Since 1993 the share has only been around 2% of the total number of patents lodged in the USA, and also seems to have settled at this level. This may be a warning sign of a lack of commitment by industry and individuals to improving environmental performance over the long term.

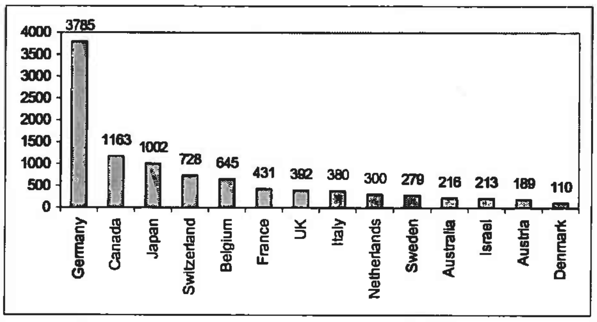

Figure 3: Shares of Environmental Patents in Total US Patents by Date of Application, 1975(1) – 1997(12)

Figure 4 shows the total number of environmental patents lodged in the USA by foreign residents, with application dates between 1975 and 2000. The overall major contributor during this period has been Germany with 3,785 patents, which accounts for more than 10% of the total number (including domestic) of US environmental patents. [3] The share of environmental patents of the overall number of patents lodged by German residents in the USA has also been increasing steadily, to around 4% in the late 1990s. Both Canada and Japan, which are second and third, respectively (see Figure 4), have less than one-third of the US patents lodged by Germany.

With 215 patents and around 0.6% of the total number of US patents, Australia ranks eleventh, which is perhaps understandable taking into account the small size of the economy. However, a number of countries with smaller populations, such as Sweden, Switzerland, Belgium and the Netherlands, have demonstrated a greater commitment than Australia to the patenting of technologies which relate to the environment.

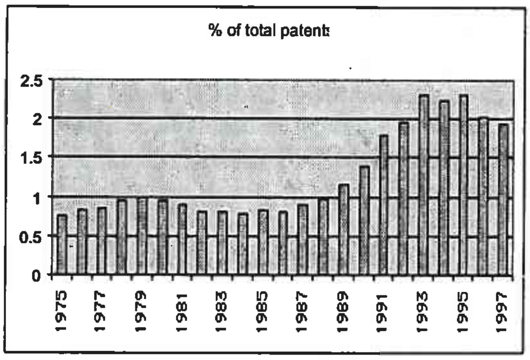

Figure 4: Environmental Patents in the USA by Selected Countries, 1975(1)-2000(12)

4. AR(1)-GARCH(1,1) AND AR(1)-GJR(1,1)

Consider the AR(1)-GARCH(1,1) model:

$$y_t = \phi_1 + \phi_2 y_{t-1} + \varepsilon_t, \qquad |\phi_2| < 1 \tag{1}$$

where

$$\begin{aligned} \varepsilon_t &= \eta_t \sqrt{h_t}, \\ h_t &= \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1}, \end{aligned} \tag{2}$$

and $\omega > 0, \alpha \geq 0, \beta \geq 0$ are sufficient conditions for $h_t > 0$.

In equations (1) and (2), the parameters are typically estimated by the maximum likelihood method to obtain Quasi-Maximum Likelihood Estimators (QMLE) in the absence of normality of η_t. The conditional log-likelihood function is given as follows:

$$\sum_t l_t = -\frac{1}{2} \sum_t \log h_t + \frac{\varepsilon_t^2}{h_t}.$$

Ling and Li [1997] showed that the local QMLE for GARCH(p,q) is consistent and asymptotic normal if $E(\varepsilon_t^4) < \infty$, and the model is stationary and ergodic

[3] The observations for Germany include data for both the former Federal and Democratic Republics.

if $E(\varepsilon_t^2) < \infty$. Using results from Ling and Li [1997] and Ling and McAleer [2001a, b] (see also Bollerslev [1986], Nelson [1990] and He and Teräsvirta [1999]), the necessary and sufficient condition for the existence of the second moment of ε_t is $\alpha + \beta < 1$ and, under normality of η_t, the necessary and sufficient condition for the existence of the fourth moment is $(\alpha + \beta)^2 + 2\alpha < 1$.

The effects of positive shocks on the conditional variance are assumed to be the same as the negative shocks in the symmetric GARCH model. In order to accommodate asymmetric behaviour, Glosten, et al. [1992] proposed the GJR model, which is defined as follows:

$$h_t = \omega + (\alpha + \gamma D_{t-1})\varepsilon_{t-1}^2 + \beta h_{t-1}, \qquad (3)$$

where $\omega > 0,\ \alpha \geq 0,\ \beta \geq 0, \gamma \geq 0$ are sufficient for $h_t > 0$, and D_t is an indicator variable defined by:

$$D_t = \begin{cases} 1, & \varepsilon_t < 0 \\ 0, & \varepsilon_t \geq 0. \end{cases}$$

The indicator variable differentiates between positive and negative shocks, in that asymmetric effects in the data are captured by the coefficient γ. Although the regularity conditions for the existence of moments for the GJR model are now known, there are as yet no theoretical results regarding the statistical properties of the model. For GJR(1,1), Ling and McAleer [2001a] showed that the regularity condition for the existence of the second moment under symmetry of η_t is $\alpha + \beta + \frac{1}{2}\gamma < 1$, and the condition for the existence of the fourth moment under normality of η_t is

$$\beta^2 + 2\alpha\beta + 3\alpha^2 + \beta\gamma + 3\alpha\gamma + \frac{3}{2}\gamma^2 < 1 \cdot$$

5. EMPIRICAL RESULTS

The primary purpose of this paper is to model the volatility of the ratio of the number of environmental and ecological patents registered in the USA to the total number of patents registered in the USA. As defined in (1)-(2) and (1)-(3), respectively, the AR(1)-GARCH(1,1) and AR(1)-GJR(1,1) models are estimated using monthly data from January 1975 to December 1997. The estimates are presented in Figures 5 and 6. Furthermore, these models are estimated using a rolling window of size 200 for the ratio. The impact of each observation on the estimates and on the second and fourth moment conditions can be investigated by examining the dynamic paths of the estimates.

The $\hat{\alpha}$ estimates for the GARCH model exhibit some interesting movements. Two dramatic increases occur in January 1976 and October 1976, followed by a 16% decline in November 1978, then remaining low for the rest of the rolling samples. Although the movements of the $\hat{\alpha}$ estimates seem dramatic, the standard deviation of $\hat{\alpha}$ is 0.0076 with a mean 0.0785, which means that short run persistence is relatively low for the number of environmental patents registered in the USA.

Movements in the $\hat{\beta}$ estimates for the GARCH model are completely different to those of the $\hat{\alpha}$ estimates. There is an upward trend, with $\hat{\beta}$ increasing from 0.825 to 0.857, then decreasing slightly and remaining at around 0.85 for the last 20 rolling samples. Furthermore, there are two dramatic declines occurring in April 1977 and June 1978. These two declines correspond to the increases in the $\hat{\alpha}$ estimates for the same rolling samples. However, the changes in the $\hat{\alpha}$ estimates for these two rolling samples are not as noticeable as the changes in the $\hat{\beta}$ estimates. The average of the $\hat{\beta}$ estimates is 0.843 with a standard deviation of 0.0092.

Although all the rolling samples satisfy the second moment condition, there are 38 rolling samples which fail to satisfy the fourth moment condition. It is interesting to note that both the second and fourth moment conditions start at a relatively low value (less than 1), but they increase dramatically in November 1975, and remain high (with the fourth moment being generally greater than 1) until early 1979. The averages of the second and fourth moment conditions are 0.923 and 1.007, respectively. Therefore, inferences arising from the GARCH model for those rolling samples may be problematic.

Interestingly, there appears to be a downward trend in the $\hat{\alpha}$ estimates for the GJR model, but there is no visible trend for the $\hat{\beta}$ estimates. However, there is a dramatic increase in the $\hat{\beta}$ estimates in April 1978, which is followed by an even greater increase in November 1978. These increases correspond to the reduction in the $\hat{\alpha}$ estimates for the same rolling samples. The movements in the $\hat{\gamma}$ estimates are even more interesting, starting at around 0.0353 and increasing steadily until June 1977. This is followed by a 16.5% decline in July 1977, but increases dramatically in the following month and stays high at around 0.23 until January 1979. There is a dramatic 45% decrease in January 1979, followed by a steady decline until October 1979, and remaining low at around 0.075 for the rest of the rolling samples. The evident lack of outliers and extreme observations indicates that such changes in the estimates occur toward the end of an abrupt transition period in the late 1970's. It is also worth noting that the $\hat{\gamma}$ estimates are highly volatile, so that asymmetric behaviour is important for modelling the number of ecological patents registered in the USA.

The mean estimates of $\hat{\alpha}$, $\hat{\beta}$ and $\hat{\gamma}$ are 0.061, 0.839 and 0.107, respectively. Note that the $\hat{\alpha}$ and $\hat{\beta}$ estimates for the GJR model are lower on average than their GARCH counterparts. Furthermore, as with the GARCH model, all rolling samples satisfy the second moment condition, and only 11 rolling samples fail to satisfy the fourth moment condition. This also suggests that the GJR model may be more appropriate than GARCH for modelling the number of ecological patents registered in the USA.

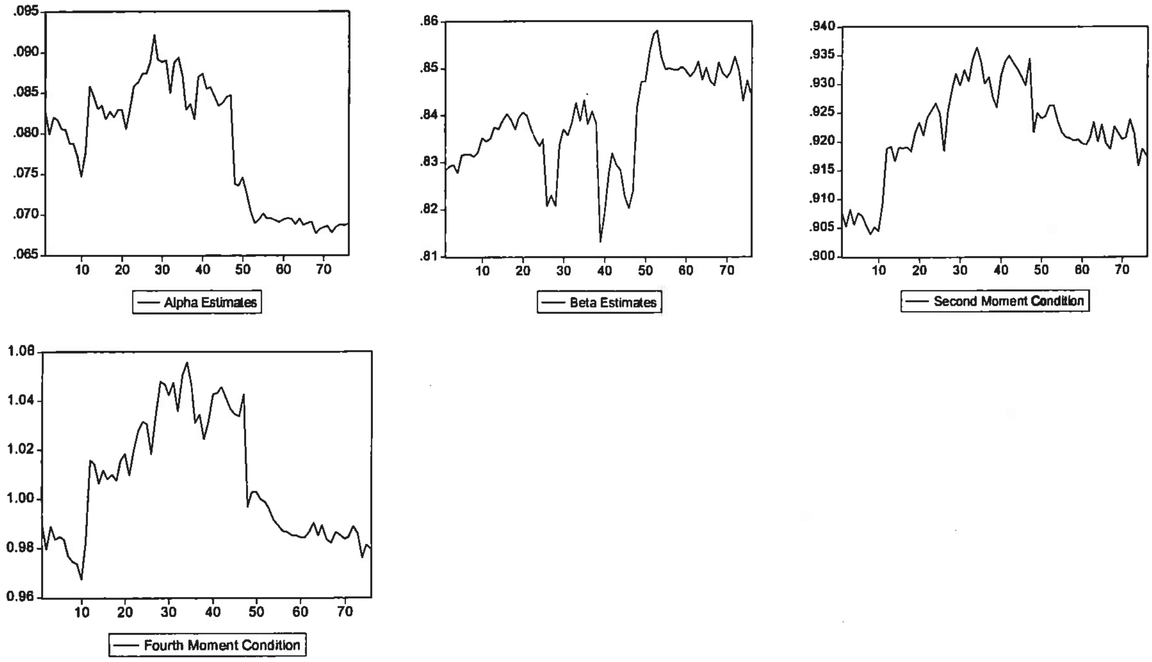

Figure 5: AR(1)-GARCH(1,1) Estimates

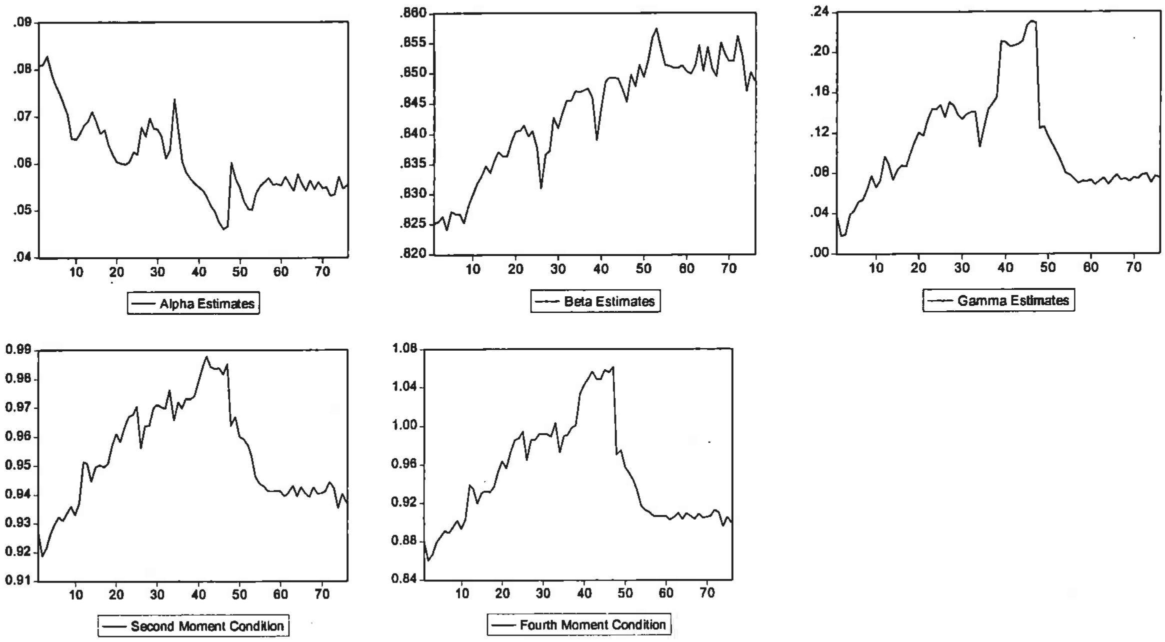

Figure 6: AR(1)-GJR(1,1) Estimates

6. CONCLUDING REMARKS

The paper analysed the trends in ecological patenting in the US market from 1975 to 1997. Using monthly data, the time-varying nature of the volatility of environmental patents registered in the USA was examined. The volatile nature of the $\hat{\gamma}$ estimates indicated the importance of accommodating asymmetric behaviour in modelling the environmental patents registered in the USA, so that the asymmetric AR(1)-GJR(1,1) model was found to be suitable.

7. ACKNOWLEDGEMENTS

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