Trends and Volatility in Japanese Patenting in the USA: An Analysis of Two Industries

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Abstract: The paper analyses the trends in patenting in the USA by Japan from 1975 to 1997, with an emphasis on electronic/electrical equipment and transportation equipment. The number of patents has been increasing steadily over time and the two industries together account for one-half of the total number of Japanese patents in the US. However, the electronic/electrical industry has been a much stronger performer, with a share of 30% (compared to around 20% for transportation) of US patents and strategically developed by the Japanese companies. The time-varying nature of the volatility of patents registered in the USA by these two Japanese industries is examined using monthly data from 1975 to 1997. The asymmetric AR(1)-GJR(1,1) model is found to be suitable for the motor and transportation industry. Both AR(1)–GARCH(1,1) and AR(1)-GJR(1,1) models provide unexpected results for the electrical and electronic industry.

***Keywords*:** Patents; Trends; Volatility; Electronic and electrical equipment; Transportation equipment; GARCH; GJR; Asymmetry

1. INTRODUCTION

Japan, once slandered as a nation of copycats, is now widely recognised as an innovator [Flath, 2000]. Government science and technology policies have actively encouraged research and development (R&D) spending, particularly from companies. In 1997, R&D expenditure represented 2.9% of the country's GDP, the largest share in the world, with contributions from the private sector being as high as 73% [DISR, 2000].

Heavy investment in R&D, coupled with strategies for quick economic returns, resulted in the immediate commercial application of most Japanese technological inventions. It also translated into activities such as foreign patenting in order to protect the intellectual rights of companies. For the period 1976 to1999, Japan had the largest total number of American patents held by foreign residents, and also ranked fourth according to patent intensity (that is, number of patents per capita), behind only two very small-sized economies (Liechtenstein and Monaco) and Switzerland [Marinova, 2001].

The broadly defined "high technology" industries of electronic/electrical equipment and transportation equipment accounted for more than 35% of the R&D spending in Japan in fiscal year 1995 [Flath, 2000]. The same industries have been intensively developed by other industrial countries, such as the USA, Germany and the Scandinavian countries. Nevertheless, the Japanese presence in international markets, and in the American market in particular, has been and continues to be highly prominent. During the 1970s and 1980s, Japan broke long-standing American monopolies in both these industries. In order to protect and extract benefits in the USA from their innovations, Japanese companies consistently register the highest number of foreign patents. In 1997, the share of granted applications lodged by Japanese residents at the US Patent and Trademark Office in all granted patent applications was 30% for transportation equipment and 17% for electronic and electrical equipment. The importance of these two industry sectors is also confirmed by the fact that in 1997 they accounted for more than 50% of the total number of US patents granted to Japanese residents. One explanation for such a high patenting activity is that Japanese companies perceive exclusive intellectual property rights, not as a reward for fundamental discoveries and inventiveness, but as a "coordinating mechanism for innovation within the market system" [Foray, 1995, p.109].

The paper examines the trends in Japanese patenting in the USA for the two industries, electronic and electrical equipment and transportation equipment. The plan of the paper is as follows. Section 2 describes the data. The statistical trends and volatility of the patent data are examined in Section 3. Section 4 briefly discusses the GARCH and GJR models. Empirical estimates are presented in Section 5, with policy implications also analysed. The main argument is that the non-stationarity exhibited by the patent data should be treated with caution. Some concluding remarks are given in Section 6.

2. DATA DESCRIPTION

The empirical study is based on patent data from the US Patent and Trademark Office (PTO), available on-line and accessible through the site's search engine (http://164.195.100.11/netahtml/search-adv.htm). The time series data consist of monthly observations for the number of patents with application dates between 1975 and 1997. The data were extracted in March 2001.

The date of lodgment of granted applications for the time series is used instead of the date of issue of patents to avoid organisational delays associated with the complicated process of receiving a patent (which includes procedures such as examination, expert review, and appeals). Consequently, the data on patents by date of application represent more accurately the process of commercial protection for intellectual property and innovative outcomes from R&D.

Although data on US patents are available from 1790, significant patenting activities occurred only after 1975, followed by an unprecedented surge in the 1980s and 1990s [Kortum and Lerner, 1999; Arundel and Kabla, 1998]. The US PTO updates the information on patents granted on a fortnightly basis. However, the time from application to the granting of a patent can be very long[1], and is estimated to be two years on average [Marinova, 2001]. Thus, any data on granted patents with application dates in 1999 and 2000 will be incomplete. Data for 1998 and some previous years will also be subject to additions from patents whose approval has taken longer than average. For this reason, data from 1975 to 1997 are used in this paper.

The classification systems used by the PTO, namely the Current US Classification and the International Patent Classification, do not provide a direct link between patent class and industry application. This issue has been reported by a number of previous researchers [see, for example, Mansfield, 1986; Pavitt, 1988; Griliches, 1990; Grupp, 1994]. In order to deal with the problem, patent classes need to be allocated to certain industries [Amendola et al., 1998]. In this paper, it was decided to use the Current US Classification[2]. The transportation equipment sector is broadly covered by 27 different patent classes, while 68 classes belong to the electronic and electrical industry.

3. GENERAL PATENT TRENDS

Figure 1 shows the monthly data for US patents in the electronic and electrical industry issued to Japanese residents, with application dates between January 1975 and December 1997. Figure 2 presents similar data for the motor vehicles and transportation industry. All variables, namely total number of Japanese patents, Japanese and total patents in the two industries, display upward trends. It is interesting to note that Japan had a relatively late start in the 1970s, but quickly caught up in the early 1980s.

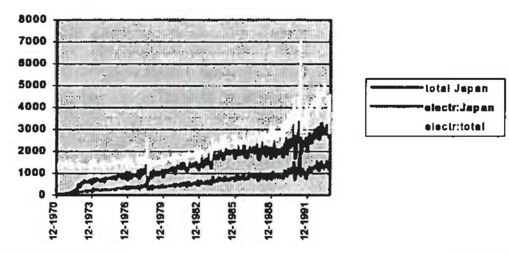

Figure 1: US Patents by Japanese Residents in the Electronic/Electrical Industry by Date of Application, January 1975 – December 1997

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[1] In the USA, patents are granted relatively quickly, particularly in comparison with the Japanese patent system where the time from application to grant can be as long as ten years [Flath, 2000].

[2] The patent classes of the Current US Classification system (or CCL), which were considered belonging to the broad area of transportation equipment industry, are the following: 114, 123, 136, 152, 157, 180, 184, 185, 187, 188, 190, 191, 192, 193, 198, 280, 290, 293, 296, 298, 301, 303, 305, 384, 440 and 506. The classes associated with electronic and electrical equipment are as follows: 109, 174, 200, 218, 219, 236, 257, 307, 310, 313, 314, 315, 318, 320, 322, 323, 324, 326, 327, 329, 330, 331, 332, 333, 344, 335, 336, 337, 338, 341, 345, 346, 349, 360, 361, 362, 364, 365, 368, 369, 371, 372, 373, 374, 375, 377, 378, 381, 382, 385, 386, 388, 392, 395, 438, 439, 445, 477, 505, 701, 702, 704, 705, 706, 707, 711, 901 and 902. The PTO has established a concordance between the US and the international patent classes, which can be accessed on its web site.

The contributions by Japan in the electronic and electrical industry are highly prominent, with the share of US patents held by Japanese residents being consistently around 30% since 1985. Respective shares for the motor vehicle and transportation industry were around 20% during the 1980s, but dropped to around 17% in the 1990s. Since the 1980s, the two industries combined have consistently represented around one-half of the total number of American patents held by Japan.

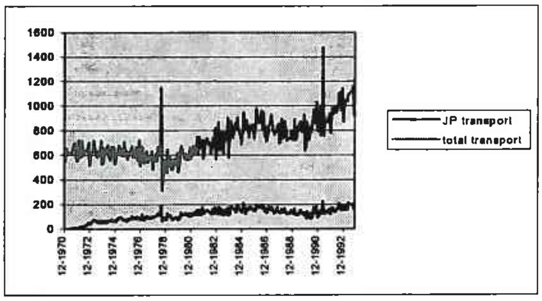


Figure 2: US Patents by Japanese Residents and in Total in the Motor Vehicle and Transportation Industry by Date of Application, January 1975 – December 1997

Previous studies, such as the European innovation survey [Arundel and Kabla 1998, p. 129], Mansfield [1986] and Pavitt [1997], claim that patents are of greatest value in sectors where the cost of copying an innovation is considerably less than the initial cost of inventions. Examples of such sectors are chemicals, petroleum and pharmaceuticals. The two industries analysed in this paper do not fall into this category, and patent protection is expected to be of much more limited importance. The cost of imitation in electronics and electrical devices, as well as for motor vehicle, parts and transportation equipment, may well be comparable to the cost of the initial inventions. It is interesting to note that, although companies in these sectors do not consider patenting to be crucial for the commercialisation of their inventions, they still apply for patents. According to Mansfield [1986], the benefits of patent protection, such as delays in imitation and bargaining power, exceed the costs involved. He also estimates that over 60% of all patentable inventions in these two industries are actually patented.

This sectoral analysis also does not provide any indication as to whether the two industries represent a technological strength for Japan. As already observed, not all industries have the same patenting propensities. Is it that Japanese companies are generally patenting across all sectors, or is it that Japan has a specific emphasis and potential in these industries? The so-called indices of technological specialisation (or 'revealed technology advantage', as described by Patel and Pavitt [1995]) provide insight. These indices are calculated according to the following formula:

$$I_{ij} = (P_{ij}/\Sigma_i P_{ij}).(\Sigma\Sigma P_{ij}/\Sigma_j P_{ij}),$$

where I_{ij} is the index for sector i in country j, and P is the number of patents.

The indices correct the contribution of a particular industry to the national number of patents with the overall patent propensity of the same industry. Thus, an index higher than 1 is indicative of a country's national strength, and the higher is the value, the more important is that industry. The opposite is also true, with lower figures representing lower levels of patenting activities. According to Paci et al. [1997, p. 33], the technical specialisation indices are preferred to simple percentage quotas of patents in each sector because some industries prefer methods other than patenting for protecting innovations, such as trade secrets, registered trade marks, know-how advantages, and economies of scale.

Figure 3 shows the trends in the technical specialisation indices for the two Japanese industries. It is interesting to note that the two sectors exhibit distinctly different behaviour. Since the late 1970s, electronic and electrical equipment has been a well-established technological strength of Japan, with its specialisation index well above 1 and with an average of just below 1.5. On the other hand, the motor vehicle and transportation equipment sector has not been important technologically as far as US patents are concerned. Japan's technological index is well below 1, with an average of 0.9 and, more importantly, exhibits a decreasing trend in more recent years.

Consequently, the higher share of Japanese patents in electronic and electrical equipment is not a specific feature of this industry, but is a strategic technological development on the part of Japanese companies. A number of studies have confirmed that patenting activities cause subsequent and immediate market changes [see, for example, Soete, 1987; Griliches et al., 1991; Ernst, 1995] in the case of German mechanical engineering, and Ernst [1997] for a case-study of the CNC-technology in the machine tool industry). This is exactly what has been witnessed with the Japanese presence in the world's electronics market. Japan has been much more pro-active in securing protection and access to American markets for this type of product than it has been in the vehicle and transportation industry. Overall, it is clear that

Japan has been far more innovative in electronics than in vehicle manufacturing.

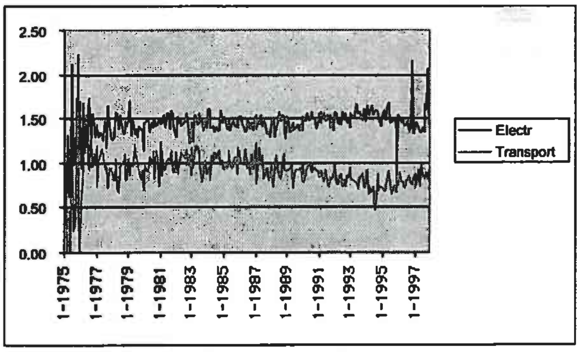


Figure 3: Technological Specialisation Indices for the Japanese Transportation and Electronic/Electrical Equipment industries, January 1975 – December 1997

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 (but not necessary) 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 normaility 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 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:

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

where $\omega > 0,\ \alpha \geq 0,\ \beta \geq 0, \gamma \geq 0$ are sufficient (but not necessary) 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

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

5. EMPIRICAL RESULTS

The primary goal of this paper is to model the volatility of the ratio between the number of patents registered in USA from the two industries in Japan by estimating the AR(1)-GARCH(1,1) and AR(1)-GJR(1,1) models, as defined in (1)-(2) and (1)-(3), respectively. These models are estimated using a rolling window of size 200 for each ratio, and the estimates are given in Figures 4 and 5. The impact of each observation on the estimates and on the second and fourth moment conditions can be investigated by examining their respective dynamic paths.

5.1 Electronic/Electrical Industry

The movements in the $\hat{\alpha}$ estimates for the GARCH model exhibit substantial fluctuations from 1975 to the late 1970's, followed by a visible downward trend from the beginning of the 1980's to the late 1990's. The fluctuations in the early rolling samples may indicate the presence of outliers, structural breaks or a period of abrupt transition. Although there are extreme observations in the 1990's, there are no outliers or extreme observations in the early rolling samples. The lack of outliers in these rolling samples indicates that the industry was experiencing a transition period during the late 1970's. Downward trends in the $\hat{\alpha}$ estimates suggest a decline in the short run persistence of unconditional shocks. Such downward trends are only slightly visible in the $\hat{\beta}$ estimates. The movements in the $\hat{\beta}$ estimates in the early rolling samples correspond to the movements in the $\hat{\alpha}$ estimates, but it remains stable after the dramatic decrease at January 1976. Interestingly, the $\hat{\beta}$ estimates remain close to or just below 0 for the rest of the rolling samples. This seems to suggest that long run persistence is relatively low. The mean estimates of $\hat{\alpha}$ and $\hat{\beta}$ are 0.233 and 0.07, respectively, with the latter being especially low for models of time-varying volatility.

Although the means of the $\hat{\alpha}$ and $\hat{\beta}$ estimates are low, in general, there are 8 rolling windows which fail to satisfy the second moment condition, and a total of 12 rolling windows which fail to satisfy the fourth moment condition. It is important to note that only rolling samples from the transition period fail to satisfy the moment conditions, and the rolling samples after January 1976 satisfy both the second and fourth moment conditions. In fact, the mean second and fourth moment conditions are 0.303 and 0.676, respectively.

The movements in the $\hat{\alpha}$ estimates for the GJR model are quite different to those in the GARCH model. Allowing asymmetric behaviour seems to have removed the downward trend in the $\hat{\alpha}$ estimates. Furthermore, the means of both the $\hat{\alpha}$ and $\hat{\beta}$ estimates increase to 0.299 and 0.182, respectively. Movements in the $\hat{\beta}$ estimates also fluctuate more dramatically than their GARCH counterparts. The fact that most $\hat{\gamma}$ estimates are negative, with a mean of –0.178, implies that, in general, negative shocks reduce the volatility in the number of electrical/electronic patents registered in the USA. This is a rather interesting finding, being in marked contrast to the empirical results using financial data in which negative shocks increase volatility.

Although the number of rolling samples failing to satisfy the second moment condition for the GJR model remains at 8, only 9 rolling samples fail to satisfy the fourth moment condition. As before, only the rolling samples from the transition period fail to satisfy the second and fourth moment conditions. The mean second and fourth moment conditions are 0.391 and 0.427, respectively, both of which are substantially different from the respective means arising from the GARCH model.

5.2 Transportation Equipment

The movements in the $\hat{\alpha}$ estimates from the early rolling samples for the GARCH model of the motor industry are as dramatic as those of the electronic/electrical industry. As before, the evident lack of outliers and extreme observations in the series, and given $\hat{\alpha}$ estimates remaining relatively high for the rest of the rolling samples, suggest that the transportation equipment industry was experiencing a period of abrupt transition. However, this period of transition seem to have ended later than the electronic/electrical industry. This may be an effect of the Oil Price shock in 1973-74. Furthermore, there seems to be a downward trend towards the end of the rolling samples, indicating a decline in the short run persistence of unconditional shocks.

Although movements in the $\hat{\beta}$ estimates from the early rolling samples correspond to those in the $\hat{\alpha}$ estimates, there is a dramatic increase in March 1978, and remain high for the rest of the rolling samples. This seems to suggest an increase in long run persistence of the unconditional shocks. The mean $\hat{\alpha}$ and $\hat{\beta}$ estimates are 0.123 and 0.603, respectively.
The transition period for the transportation industry finished later than the electronic/electrical industry, so that only 2 and 7 rolling samples fail to satisfy the second and fourth moment conditions, respectively. As with the case with the electronic/electrical industry, only rolling samples from the transition period fail to satisfy these moment conditions. The mean second and fourth moment conditions are 0.726 and 0.829, respectively.

Movements in the $\hat{\alpha}$ estimates for the GJR model are somewhat different from their GARCH counterparts. There is a decline in the $\hat{\alpha}$ estimates from the early rolling samples and, even more disturbingly, some of the estimates during these samples are negative. This is followed by a dramatic increase in January 1976, where the $\hat{\alpha}$ estimates increase to 0.09 and remain at a similar level until October 1977. After October 1977, the $\hat{\alpha}$ estimates remain just above 0, with a slight increase towards the end of the rolling samples. The mean of the $\hat{\alpha}$ estimates for the GJR model is 0.038, which is substantially lower than for the GARCH model.

The mean of the $\hat{\beta}$ estimates for the GJR model has decreased to 0.522, although their movements remain qualitatively similar to those for the GARCH model. Movements in the $\hat{\gamma}$ estimates are quite interesting. Starting at around 0.1 in the early rolling samples, the $\hat{\gamma}$ estimates increase dramatically to 0.58 on January 1976, before decreasing steadily over time, with a mean of 0.242 over the full sample. This suggests that the asymmetric effects generally decline over time.

Although the mean second and fourth moment conditions are relatively low at 0.646 and 0.682, respectively, more rolling samples fail to satisfy the second and fourth moment conditions for GJR than for GARCH. A total of 6 and 9 rolling samples fail to satisfy the second and fourth moment conditions, respectively. These results raise issues regarding the validity of inferences arising from the GJR model.

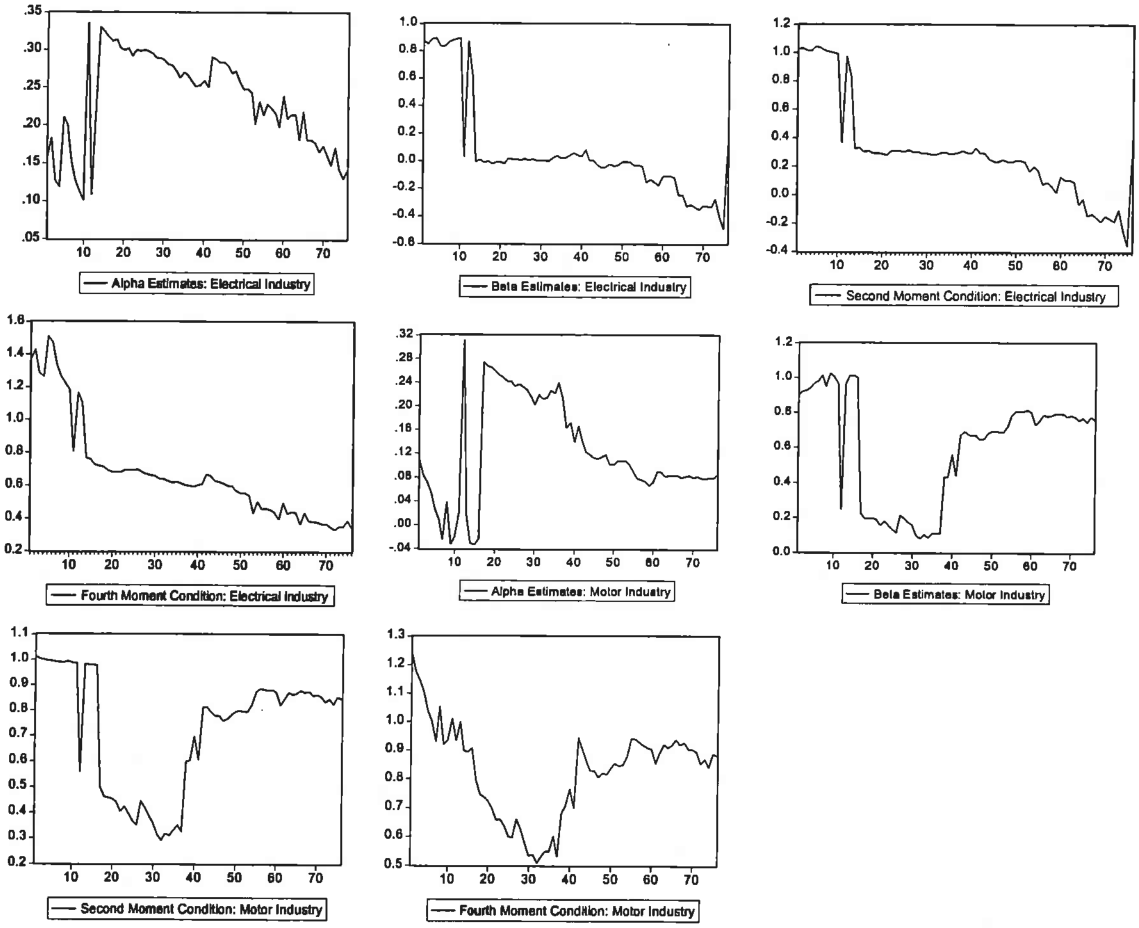
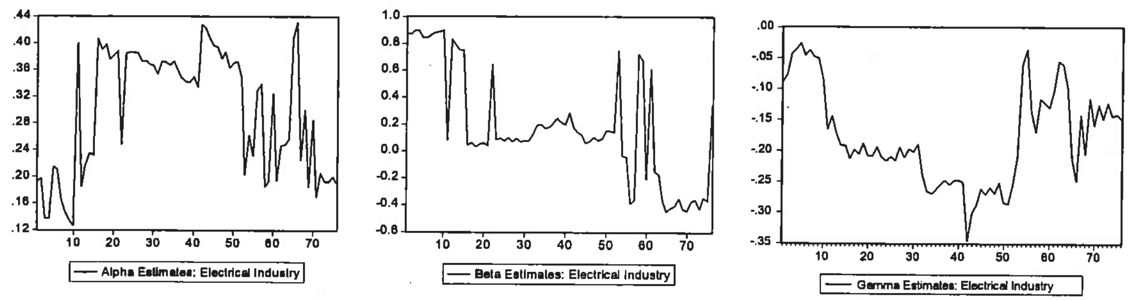


Figure 4: AR(1)-GARCH(1,1) Estimates



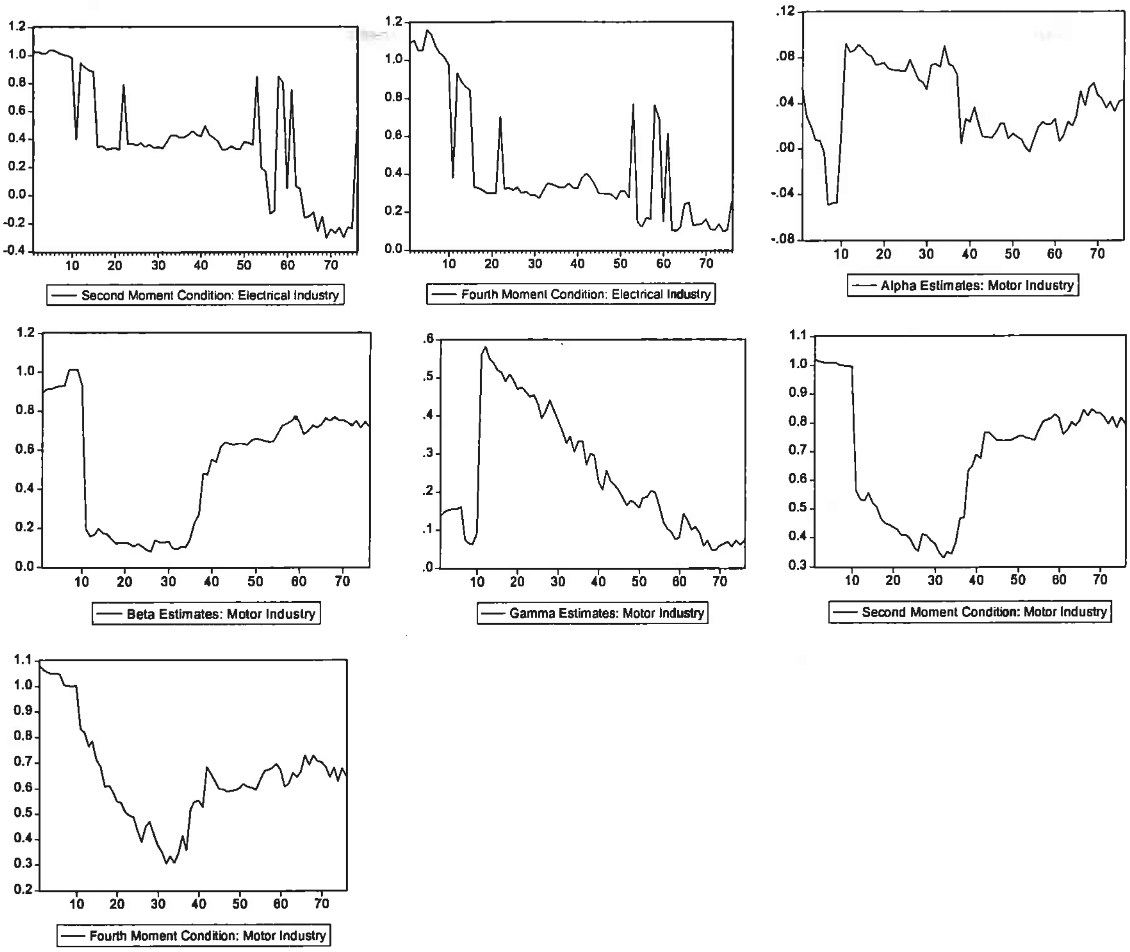


Figure 5: AR(1)-GJR(1,1) Estimates

6. CONCLUDING REMARKS

The paper analysed the trends in patenting in the USA by Japan from 1975 to 1997, with an emphasis on electronic/electrical equipment and transportation equipment. The time-varying nature of the volatility of patents registered in the USA by these two Japanese industries was examined using monthly data. The asymmetric AR(1)-GJR(1,1) model is found to be suitable for the motor and transportation industry, though the effects of asymmetry seemed to be declining over the past period. Estimates from both AR(1)-GARCH(1,1) and AR(1)-GJR(1,1) models for the electrical/electronic industry provided unexpected results, and further investigation is required to understand the time-varying nature of the volatility of patents registered in the USA by the Japanese electrical/electronic industry.

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