Trends and Volatilities in Patents Registered in the USA

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Abstract: The paper presents an overview of patent trends for the top 12 foreign patenting countries in the US market from 1975 to 1997. Japan is ranked first in terms of foreign patents registered in the USA, followed by Germany. The time-varying nature of the volatility of Australian, Japanese and German patents registered in the USA are examined using monthly data. The asymmetric AR(1)-GJR(1,1) model is found to be suitable for Australia and Japan, while the best model for Germany is the symmetric AR(1)-GARCH(1,1) model.

***Keywords*:** Patents; Trends; Volatility; GARCH; GJR; Asymmetry

1. INTRODUCTION

Trends in patent registration have frequently been used to describe a country's technological capabilities, and have acted as a proxy for innovation [see, for example, Pavitt, 1988; Patel and Pavitt, 1995; Griliches et al. 1989, and Marinova, 2001]. Having the world's largest economic market, the USA has consistently been a destination for registering patents by innovative American and foreign companies, as well as individuals who have aspired to commercialise new technologies. Consequently, the patents registered by the US Patent and Trademark Office (PTO) represent an excellent source of information regarding technological strengths and market ambitions.

Most of the research on granted patents in the USA has examined snapshot images representing the patent activities for a particular time period, based on a single-year or aggregated annual information base. For example, patent data have been used in econometric regression models to analyse issues such as what determines the decisions by companies to patent innovations [Duguet and Kabla, 2000]. Auctions and game modelling have also been applied to study the processes of patent acquisition and/or patent renewal [Waterson and Ireland, 2000; and Crampes and Langinier, 2000]. Patent numbers have been used as a measure of R&D output in a number of production function studies [Goel, 1999]. Cross-country correlations using patent data are also very common [see, for example, the study by Pianta, 1998] and, on the occasions when time series data are analysed, stationarity tests are generally not conducted [see, for example, Archibugi and Pianta, 1998].

Volatility in patent registration has not been analysed in the literature. The aim of this paper is to examine the trends and volatilities in patents registered in the USA using monthly time series data from 1975 to 1997, for the ratio of the number of patents lodged at the US PTO from a given country to the total number of patents registered in the USA.

The plan of the paper is as follows. Section 2 describes the data used. Section 3 discusses the AR(1)-GARCH(1,1) and AR(1)-GJR(1,1) models. The empirical results regarding trends and volatilities in patent registration are presented in Section 4, which is followed by some concluding remarks in Section 5.

2. DATA DESCRIPTION

The US economy is currently the largest market in the world. For over two centuries, the USA has also firmly adopted the patent system as a mechanism for market protection and stimulation of innovative activities. [Patent laws were introduced in the USA in the 1780's.] According to Goel [1999], the patent system is supported by government as a tool to correct market imperfections, thereby allowing imitating firms to benefit from costly technologies developed elsewhere. It assures appropriability of returns to the inventors[1], and benefits society by making the revealed information public knowledge after the expiry of the patent.[2]

The American patent system has steadily attracted companies and individuals from around the world interested in developing technologies and establishing trade links. In absolute numbers, the US patent office receives by far the largest number of foreign applications [Archibugi, 1992]. Not surprisingly, close to 50% of all patents in the USA are granted to foreigners [Griliches, 1990; Goel, 1999].

There are, however, large variations between firms and national economies in terms of what costs they can afford (such as patenting fees) to protect their inventions or to buy the rights of usage of patents originating elsewhere. This paper examines the patenting behaviour of the top 12 foreign economies (with respect to the total number of American patents held), and provides a basis for further analysis of a particular performance. The countries included in the list are presented in Table 1. The country which has the largest number of American patents held by foreigners is Japan, followed distantly by Germany. Of the top twelve countries, the highest patent intensity (as measured by the number of patents per capita) is held by Switzerland, followed by Japan and Sweden.[3]

The time period selected for the analysis covers all granted patents with dates of application lodgement between January 1975 and December 1997 (inclusive). Patent data have been obtained from the official Internet webpage of the US PTO using the search engine available on the site. Although data prior to 1975 are also available, the search algorithm does not provide consistency with the data after 1975. In addition, previous studies have indicated that, during the 1980s and 1990s, the number of patents by foreign countries in the USA surged at an unprecedented rate [see, for example, Patel and Pavitt 1995; Kortum and Lerner, 1999; and Arundel and Kabla, 1998].

Table 1.US patents and patent intensity for selected countries, January 1975 – December 1997

Country	No. of US patents, 1975(1) - 1997(12)	Patent intensity (patents per million of 1997 population)
1 Japan	395,067	3,140
2 Germany	159,437	1,942
3 France	67,955	1,159
4 Canada	48,004	1,584
5 Switzerland	32,862	4,556
6 Italy	28,362	494
7 Taiwan	23,210	1,073
8 Netherlands	22,850	1,464
9 Sweden	21,000	2,369
10 UK	17,378	295
11 Korea	16,323	354
12 Australia	11,694	630
Total top 12	844,142	1,589
(% of top 12)	(38%)	-
Total US patents	2,218,836	-

Source of data:
http://164.195.100.11/netahtml/search-adv.htm and http://www.census.gov/cgi-bin/ipc/idbsprd

Data are also available on more recent patents issued, including 1998 to 2000. However, as it takes on average two years between application for a patent and granting of a patent, this information was considered to be incomplete for purposes of estimating volatilities and conducting statistical tests.

2.1 General Country Trends

Figures 1, 2 and 3 show the trends in foreign patenting in the USA, based on annual data. All the countries exhibit increasing trends. However, the top 12 performers can be divided into two groups. The first group (Group A) includes Japan, France, Canada, Taiwan, Korea and UK, all of which are countries with much higher rates of increase in patenting. Taiwan, Korea and the UK (and to a lesser extent, Canada) accomplished high rates of increase in the 1990s. Of particular interest are the East Asian countries, which have started to close the technology gap with the West. According to Patel and Pavitt [1998, p.59], "technology in Taiwan and South Korea is now attaining world best practice levels in an increasing number of fields – a striking example of technological catch up compared with the advanced countries."

[1]A patent in the USA confers to the inventor a 17-year monopoly over the technical idea(s) covered but a large number of patented inventions could remain dormant and never reach the innovation stage [Oi, 1995].

[2] Being an invention of the old neoclassical economic model, the patent system also incorporates a number of deficiencies. For example, it had been used to establish monopoly positions in industries, such as aluminum or shoe manufacturing [Mansfield, 1993]. The patent fees can also be highly prohibitive and, hence, discriminative against potential applicants who cannot afford them. It also cannot accommodate a number of new ethical and economic issues emerging from the scientific and technological advances in the field of biotechnology, pharmaceutics or information technologies. Scotchmer [1991, p.40] describes the patent system as "a very blunt instrument trying to solve a very delicate problem."

[3] The small economies of Liechtenstein and Monaco have higher patent intensities than Switzerland [Marinova, 2001] but, as their absolute patent numbers are very small, they are not included in the analysis.

The second group (Group B) consists of Germany, Switzerland, Italy, the Netherlands, Sweden and Australia. These countries have demonstrated a stable upward trend over the 23-year period, which is more or less consistent with the increase of the overall number of American patents.

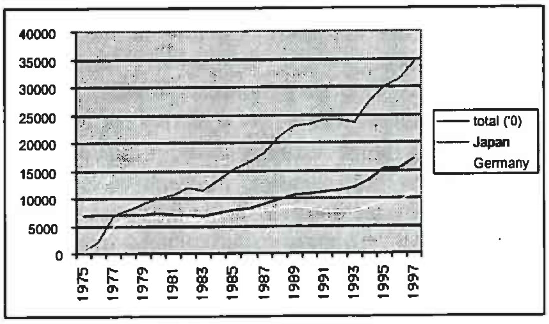


Figure 1. US patents: total and held by Japan and Germany; 1975-1997 (as at 13 April 2001).

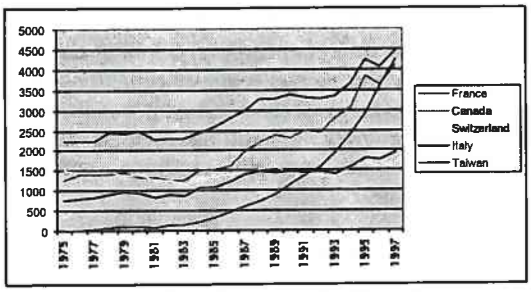


Figure 2. US patents from France, Canada, Switzerland, Italy and Taiwan, 1975-1997 (as at 13 April 2001).

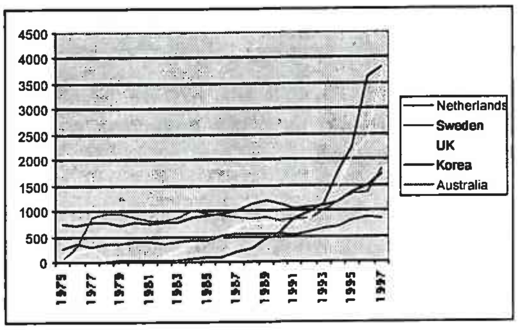


Figure 3. US patents from the Netherlands, Sweden, UK, Korea and Australia, 1975-1997 (as at 13 April 2001).

3. AR(1)-GARCH(1,1) AND AR(1)-GJR(1,1) MODELS

The primary purpose of this paper is to model the volatility of the ratio of the number of patents registered in the USA from a given country to the total number of patents registered in the USA. The AR(1)-GARCH(1,1) and AR(1)-GJR(1,1) models, as defined in (1)-(2) and (1)-(3) respectively, are estimated using data from three countries, namely Australia, Germany and Japan. Furthermore, these models are estimated using a rolling window of size 200 for each 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.

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 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, 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 $\omega > 0, \alpha \geq 0, \beta \geq 0$ 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 $\beta^2+2\alpha\beta+3\alpha^2+\beta\gamma+3\alpha\gamma+\frac{3}{2}\gamma^2<1$.

4. EMPIRICAL RESULTS

This section presents the empirical results for Australia, Japan and Germany in Figures 4 and 5.

4.1 Australia

Both the $\hat{\alpha}$ (ARCH) and $\hat{\beta}$ (GARCH) estimates in the GARCH model exhibit downward trends. This causes both the short run and long run persistence of the unconditional shocks to decrease, in general, implying a reduction in volatility in the number of patents in Australia. All sub-samples satisfy the second moment condition, but 63 rolling windows fail to satisfy the fourth moment condition. This suggests that, while the data are stationary for all rolling windows, the QMLE may not be consistent or asymptotic normal for those sub-samples. Thus, valid inferences are problematic.

The movements of the $\hat{\alpha}$ estimates in the GJR model for Australia are similar to those for the GARCH model. Although there is an increase in the average of the $\hat{\alpha}$ estimates from 0.125 to 0.15, the presence of the downward trend is still obvious. The movements of the $\hat{\beta}$ estimates in the GJR model are different to their counterparts in the GARCH model, as the downward trend is no longer present and there are some dramatic movements towards the end of the rolling samples. The average of the $\hat{\beta}$ estimates decreases from 0.75 to 0.6. Moreover, all rolling samples satisfy the second and fourth moment conditions, with averages of 0.775 and 0.664, respectively. Although the average of the $\hat{\gamma}$ estimates is relatively low at 0.05, the dynamic path of the $\hat{\gamma}$ estimates suggests the presence of asymmetry. The movements of the $\hat{\gamma}$ estimates are as dramatic as the $\hat{\alpha}$ and $\hat{\beta}$ estimates, which suggest that it is clearly appropriate to use an asymmetric model for Australia.

4.2 Japan

The movements of the $\hat{\alpha}$ estimates for the GARCH model are relatively low in the early rolling samples, but rise dramatically from late 1975 to 1976. This may indicate the effect of an outlier, structural break or a period of abrupt transition. As the $\hat{\alpha}$ estimates remain high for the rest of the rolling samples, the evident lack of outliers or extreme observations in the series seems to suggest that Japan was experiencing a transition period in the mid 1970's. Movements in the $\hat{\beta}$ estimates correspond to movements in the $\hat{\alpha}$ estimates, as the dynamic path begins with high $\hat{\beta}$ estimates which decrease dramatically. The averages of the $\hat{\alpha}$ and $\hat{\beta}$ estimates are 0.454 and 0.305, respectively. Surprisingly, 6 rolling samples fail to satisfy the second moment condition, even though the average second moment condition is 0.759. Disturbingly, all rolling samples fail to satisfy the fourth moment condition, with an average of 1.499.

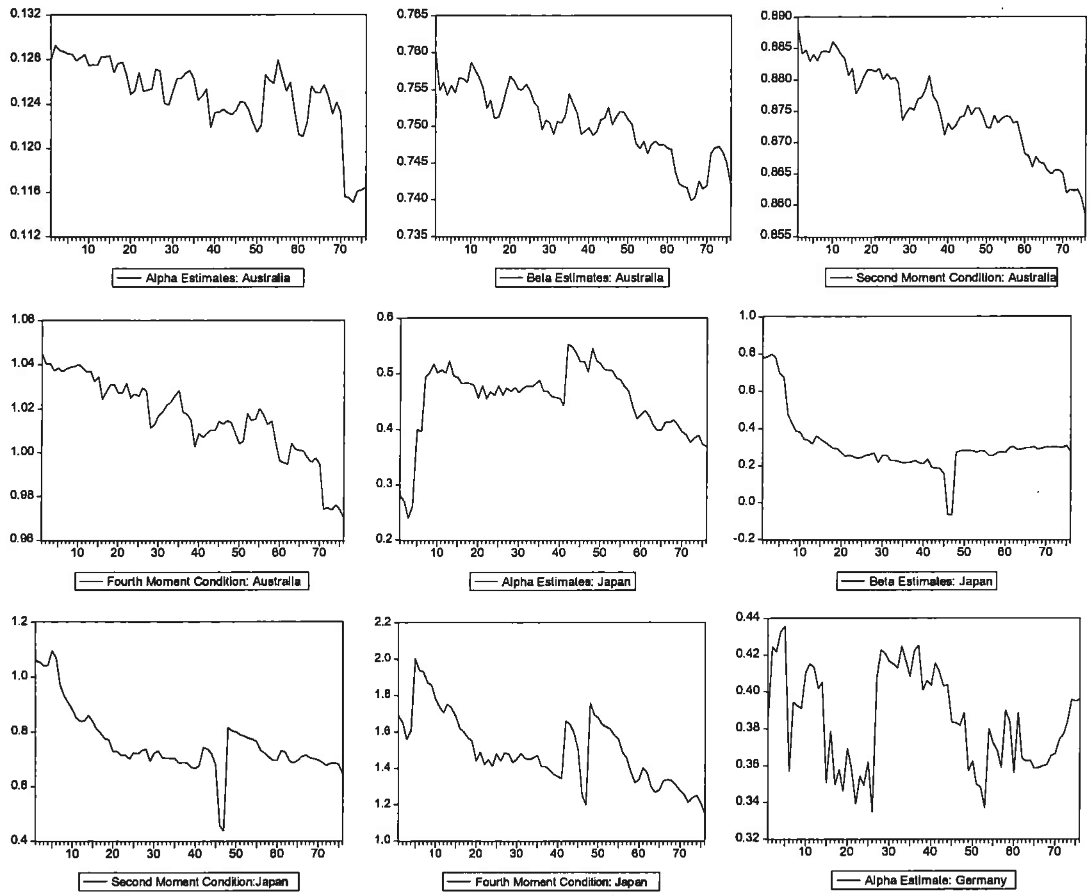
In terms of the magnitude of the $\hat{\gamma}$ estimates, the effects of asymmetry seem to be more important in Japan than in Australia. The average of the $\hat{\gamma}$ estimates is 0.335, which means that negative shocks have positive effects on volatility in the short run, as well as long run persistence. Furthermore, the average of the $\hat{\alpha}$ estimates decreases to 0.195, but the average of the $\hat{\beta}$ estimates increases to 0.383 compared with its GARCH counterpart.

Estimation of the GJR model also improves the number of rolling windows that satisfy the fourth moment condition compared with GARCH. Only 30 rolling windows fail to satisfy the fourth moment condition, but 6 rolling windows still fail to satisfy the second moment condition.

4.3 Germany

The movements in the $\hat{\alpha}$ and $\hat{\beta}$ estimates of the GARCH model are quite different from the previous two countries. Most noticeable is the dramatic increase (decrease) in the $\hat{\alpha}$ ($\hat{\beta}$) estimates in April 1977. The $\hat{\alpha}$ estimate increases from 0.335 to 0.408, and the $\hat{\beta}$ estimate decreases from 0.781 to an unacceptable –0.096. A close examination of the series reveals that April 1977 is the end of a transition period. However, there are two noticeable extreme observations in the series, namely October 1982 and June 1985. Unfortunately, these two extreme observations remain in all rolling windows, so that their empirical effects are difficult to identify. An identical number of 26 rolling windows fail to satisfy the second and fourth moment conditions of the GARCH model, with averages of 0.584 and 1.265, respectively. Indeed, some of the rolling estimates of the fourth moment for GARCH exceed 2, which is highly problematic.

Movements in the $\hat{\alpha}$ and $\hat{\beta}$ estimates for the GJR model are qualitatively similar to those for the GARCH model. Interestingly, the average of the $\hat{\gamma}$ estimates is –0.038, suggesting that negative shocks have a negative impact on volatility for Germany. In fact, examining the dynamic path of the $\hat{\gamma}$ estimates reveals that they are negative for most of the rolling samples. Furthermore, an identical number of 30 rolling samples fail to satisfy the second and fourth moment conditions for the GJR model, with averages of 0.624 and 0.805, respectively. This indicates that the GJR model is not more appropriate than its GARCH counterpart for Germany. Moreover, the rolling samples that fail to satisfy the second and fourth moment conditions begin before April 1977. Thus, it may be more appropriate to employ models such as the Smooth Transition Autoregressive (STAR) GARCH-type (STAR-GARCH) models to fully capture the characteristics of the data for Germany (see van Dijk, Teräsvirta and Franses [2001] for a comprehensive survey of STAR-type models).



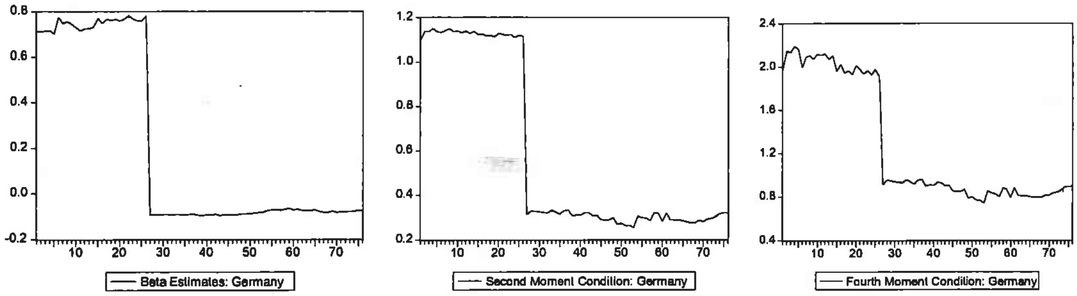
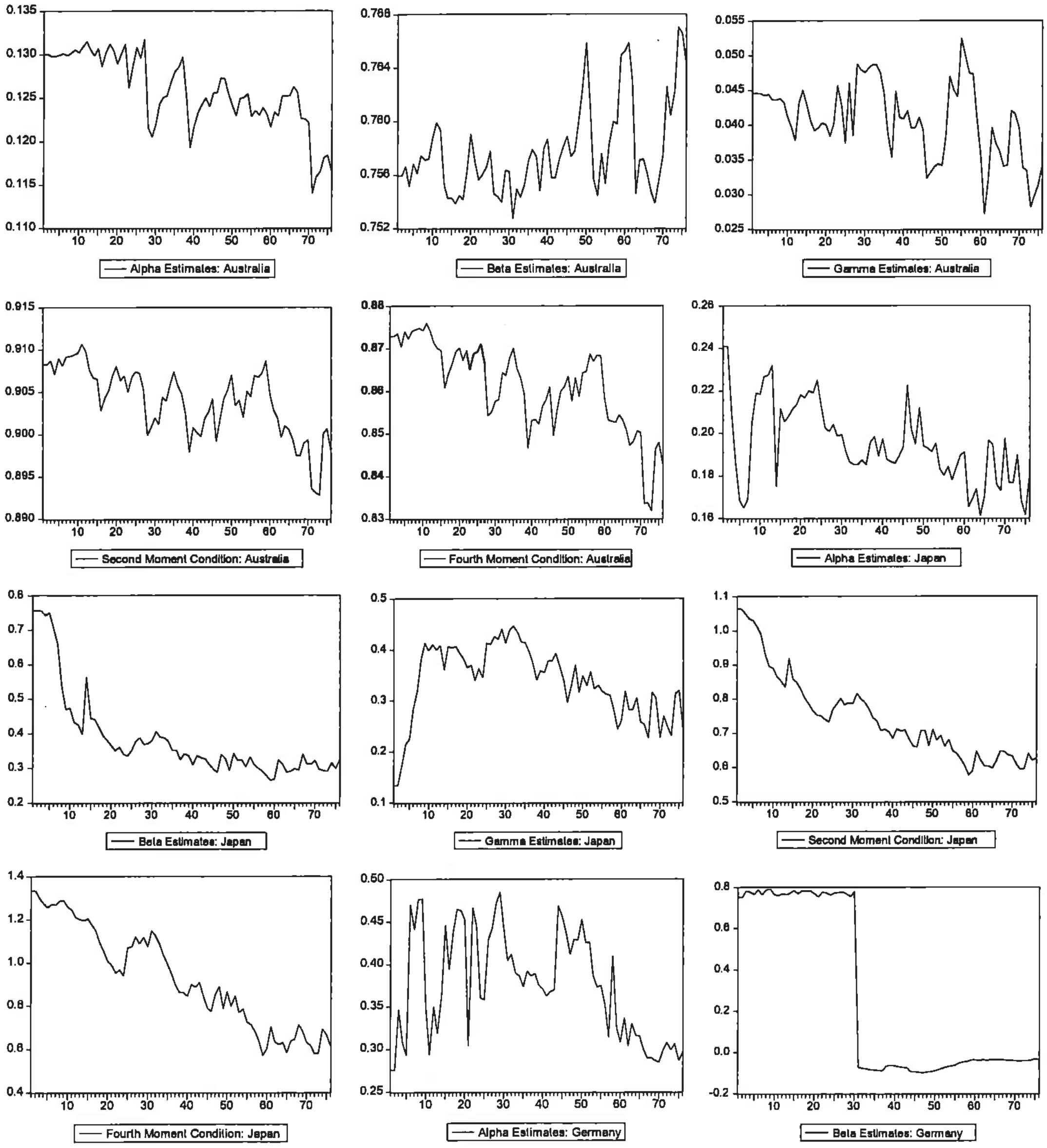


Figure 4: AR(1)-GARCH(1,1) Estimates



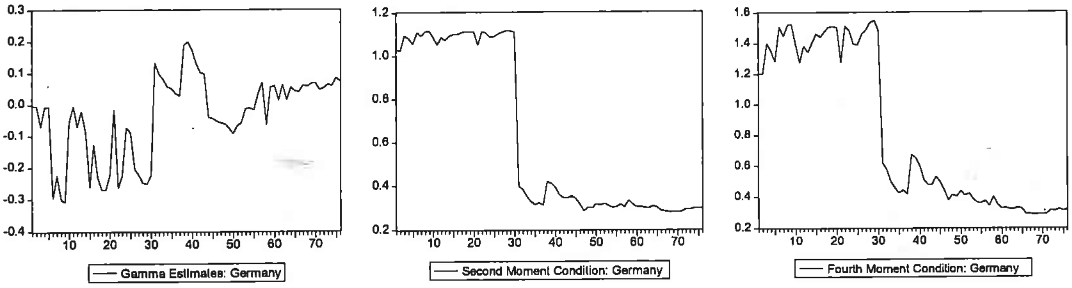


Figure 5: AR(1)-GJR(1,1) Estimates

5. CONCLUDING REMARKS

The paper presented an overview of patent trends for the top 12 foreign patenting countries in the US market from 1975 to 1997. The time-varying nature of the volatility of Australian, Japanese and German patents registered in the USA were examined using monthly data. The asymmetric AR(1)-GJR(1,1) model was found to be suitable for Australia and Japan, while the best model for Germany was the symmetric AR(1)-GARCH(1,1) model.

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