An International Comparison of Foreign Patents Registered in the USA

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Abstract: This paper analyses trends and volatilities in registered patents for the top 12 foreign patenting countries in the USA. In terms of total US patents by foreign countries, Japan is ranked first, followed distantly by Germany and then France. Patent registrations from each of the 12 countries have increased steadily over time, but at different rates. Using monthly time series data for 1975-1998, the time-varying volatility of the patents ratio, namely US patents registered by each of the top 12 foreign countries relative to total US patents, is examined in detail. International rankings based on both the number of patents and patent intensity (or patents per capita) are provided. The asymmetric AR(1)-EGARCH(1,1) model is found to be suitable for most countries, while the AR(1)-GARCH(1,1) and AR(1)-GJR(1,1) models also provide useful insights. Non-nested testing procedures are used to discriminate between GARCH(1,1) and EGARCH(1,1), and between GJR(1,1) and EGARCH(1,1).

Keywords: Patents, trends, volatility, GARCH, GJR, EGARCH, asymmetry, regularity conditions, asymptotic theory, international rankings, non-nested tests.

1. INTRODUCTION

Trends in patent registrations have frequently been used to describe a country's technological capabilities and intellectual property, and have acted as a proxy for innovation (see, for example, Pavitt, 1988; Patel and Pavitt, 1995; Griliches, 1986; and Marinova, 2001). Having the world's largest economic market, the USA has consistently been a destination for registering patents by innovative US and foreign companies, as well as by individuals with intentions to commercialise new technologies. Consequently, patents registered at the US Patent and Trademark Office (PTO) represent an excellent source of information regarding technological strengths, intellectual property and market ambitions.

Most of the research on patents granted in the USA has examined snapshot images representing patent activities for a particular time period, based on a single year or on an aggregated annual information base. For example, patents data have been used in econometric models to analyse the factors affecting decisions by companies to patent innovations (Duguet and Kabla, 2000). Auction models have also been used to analyse 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 several production function studies (Goel, 1999). Cross-country correlations using patents data are also very common (see, for example, Pianta, 1998). When time series data have been analysed, stationarity tests have typically not been reported (see, for example, Archibugi and Pianta, 1998).

Volatility in patent registrations has typically not been analysed in the literature. The aim of this paper is to examine the trends in patents registrations and volatility in the patents ratio, namely patents registered at the US PTO by each of the top 12 foreign countries relative to total US patents, using monthly time series data from 1975 to 1998.

The plan of the paper is as follows. Section 2 describes the trends and volatility in the data used, and provides international rankings based on both the number of patents and patent intensity (or patents per capita). Section 3 discusses the structural and asymptotic properties of the time-varying AR(1)-GARCH(1,1), AR(1)-GJR(1,1) and AR(1)-EGARCH(1,1) models, and uses non-nested testing procedures to discriminate between GARCH and EGARCH, and between EGARCH and GJR. Empirical results for the volatilities in the patents ratio for the top 12 foreign countries, and discrimination based on non-nested tests, are discussed in Section 4. Some concluding remarks are given in Section 5.

2. TRENDS AND VOLATILITIES IN PATENTS DATA

2.1 Data

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

Patent laws were introduced in the USA in the 1780s. The US patents system has steadily attracted international companies and individuals interested in developing technologies and establishing trade links. In absolute numbers, the US PTO 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), as will be seen in the discussion regarding Table 1 below.

There are, however, large variations between firms and countries in terms of what costs they can afford (such as patenting fees) to protect their inventions or to buy patents rights originating elsewhere. This paper examines trends and volatility in the patents ratio, or US patents of the top 12 foreign countries relative to total US patents. The 12 foreign countries are listed in Table 1. The foreign country with the largest number of US patents is Japan, followed distantly by Germany and then France. Of the top 12 countries, the highest patent intensity (or patents per capita) is held by Switzerland, followed by Japan, Sweden and Germany.[3] France and Italy have numerous patents but relatively low patent intensities, whereas Switzerland and Sweden have relatively few patents but high patent intensities.

The sample period selected for the empirical analysis covers all granted patents with dates of lodged applications between January 1975 and December 1998 (inclusive), with the data extracted in April 2002. Patents data have been obtained from the official Internet webpage of the US PTO using the search engine available on the site (http://164.195.100.11/netahtml/search-adv.htm), and population figures from (http://www.census.gov/ipc/www/idbprint.html). The date of lodgement 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 issuing 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 prior to 1975 are also available, the US PTO 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; 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, 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 for purposes of estimating volatilities and conducting statistical tests. For this reason, data from 1975 to 1998 are used in this paper.

2.2 Trends in Patents Data

Figures 1, 2 and 3 show the annual trends in total US patents and US patents held by foreign countries. All the countries exhibit increasing trends. However, the top 12 performers can be divided into two groups. Group A includes Japan, France, Canada, Taiwan, (South) Korea and UK, all of which have much higher rates of increase in patenting than those in Group B (given below). Taiwan, Korea and the UK (and to a lesser extent, Canada) had high rates of increase in the 1990s. Of particular interest are the two 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.”

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 reasonably consistent with the increase in the overall number of total US patents.

Not surprisingly, the correlations of US patents for the top 12 countries and total US patents are very high, in general, and are given in Tables 2 and 3. As shown in Table 3, Canada is ranked first with a correlation coefficient of 0.979, follow closely by France and Japan with 0.922 and 0.916, respectively. Furthermore, correlations within the top 12 countries are also high, in general, as shown in Table 2. US patent registrations from Taiwan and UK have the highest correlation of 0.957, followed by Taiwan and Korea with 0.926. Canada and France are ranked third with a correlation coefficient of 0.903. Interestingly, five of the six countries from Group A, namely Canada, France, UK, Korea and Taiwan, are highly correlated among themselves.

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[1] A patent in the USA confers to the inventor a 17-year monopoly over the technical idea(s) covered. However, a large number of patented inventions can remain dormant without ever reaching the innovation stage (Oi, 1995).

[2] Being an invention of the neoclassical economic model, the patents system also incorporates a number of deficiencies. For example, it has been used to establish monopoly positions in industries, such as aluminum or shoe manufacturing (Mansfield, 1993, 1995). Patent fees can also be highly prohibitive, which can discriminate against potential applicants. The patents system cannot accommodate a number of ethical and economic issues newly emerging from the scientific and technological advances in the fields of biotechnology, pharmaceutical or information technologies. Scotchmer (1991, p.40) describes the patents 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 that of Switzerland (Marinova, 2001), but are not included in the analysis as their patent numbers are very small.

2.3 Volatilities in Patents Ratios

The volatilities in the patents ratios can be found in Figures 4, 5 and 6. Countries such as The Netherlands and Sweden are extremely volatile, especially in the late 70s and early 80s. Asian countries such as Taiwan and Korea have low volatilities during the early periods, but both become volatile in the 90s, which can be viewed as another reflection of technological catch up (as suggested in Patel and Pavitt (1998, p.59)). Volatility clustering, as commonly found in financial data, also appears to be a common feature in the patents data, particularly for Italy, The Netherlands, and Switzerland. Some countries, such as Australia, Korea, Taiwan and Japan also appear to have outliers in the volatilities, which is another common feature of financial time series data. Undoubtedly, these graphs provide strong support for the time-varying nature of volatilities in patents ratios, which justifies the need for modelling conditional variances.

3. GARCH, GJR AND EGARCH

The primary purpose of this section is to obtain an optimal model of the volatility of the patents ratio, namely the number of registered US patents from a given foreign country to the total US patents. This new approach is based on Engle's (1982) path-breaking idea of capturing time-varying volatility (or risk) using the autoregressive conditional heteroskedasticity (ARCH) model, and subsequent developments forming the ARCH family of models (see, for example, the surveys of Bollerslev, Chou and Kroner, 1992; Bollerslev, Engle and Nelson, 1994; and Li, Ling and McAleer, 2002). Of these models, the most popular has been the generalised ARCH (GARCH) model of Bollerslev (1986), especially for the analysis of financial data. In order to accommodate asymmetric behaviour between negative and positive shocks (or movements in the time series), Glosten, Jagannathan and Runkle (1992) proposed the GJR model. Some further developments have been suggested by Wong and Li (1997), He and Teräsvirta (1999), and Ling and McAleer (2002a, b, c).

Consider the AR(1)-GARCH(1,1) model for the patents ratio, y_t:

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

where the shocks (or movements in the patents ratio) are given by:

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

and $\omega > 0, \alpha \geq 0, \beta \geq 0$ are sufficient conditions to ensure that the conditional variance $h_t > 0$, and $\eta_t \sim iid(0,1)$. The ARCH (or α) effect indicates the short run persistence of shocks, while the GARCH (or β) effect indicates the contribution of shocks to long run persistence (namely, $\alpha + \beta$).

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:

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

Ling and Li (1997) showed that the GARCH(p,q) model is stationary and ergodic if $E(\varepsilon_t^2) < \infty$. Ling and McAleer (2002c) showed that the QMLE for GARCH(p,q) is consistent if the second moment is finite, that is, $E(\varepsilon_t^2) < \infty$. For GARCH(p,q), Ling and Li (1997) demonstrated that the local QMLE is asymptotically normal if the fourth moment is finite, that is, $E(\varepsilon_t^4) < \infty$, while Ling and McAleer (2002c) proved that the global QMLE is asymptotically normal if the sixth moment is finite, that is, $E(\varepsilon_t^6) < \infty$. Using results from Ling and Li (1997) and Ling and McAleer (2002a, 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 for GARCH(1,1) is $\alpha + \beta < 1$ and, under normality, the necessary and sufficient condition for the existence of the fourth moment is $(\alpha + \beta)^2 + 2\alpha^2 < 1$.

For the univariate GARCH(p,q) model, Elie and Jeantheau (1995) and Jeanthau (1998) established a weak sufficient condition for consistency of the QMLE, and Boussama (2000) derived asymptotic normality under the same condition. The sufficient condition for the QMLE of GARCH(1,1) to be consistent and asymptotically normal is given by the log-moment condition, namely $E(\log(\alpha\eta_t^2 + \beta)) < 0$. However, this condition is not easy to check in practice as it involves an unknown random variable and unknown parameters. The extension of this weak condition to multivariate models is particularly complicated (for further details, see Jeantheau (1998)). Although the sufficient conditions for consistency and asymptotic normality of the QMLE for univariate GARCH(p,q) given in Ling and Li (1997) and Ling and McAleer (2002a, b), and for multivariate GARCH(p,q) in Ling and McAleer (2002c), are stronger than the log-moment condition, they are also more straightforward to check in practice.

The effects of positive shocks (or upward movements in the patents ratio) on the conditional variance, h_t, are assumed to be the same as the negative shocks (or downward movements in the patents ratio) in the symmetric GARCH model. In order to accommodate asymmetric behaviour, Glosten, Jagannathan and Runkle (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 $\omega > 0, \alpha + \gamma \geq 0, \beta \geq 0$ are sufficient conditions 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, so that asymmetric effects in the data are captured by the coefficient γ, with $\gamma > 0$. The asymmetric effect, γ, measures the contribution of shocks to both short run persistence, $\alpha + \frac{\gamma}{2}$, and long run persistence, $\alpha + \beta + \frac{\gamma}{2}$. Although the regularity conditions for the existence of moments for the GJR model are now known (Ling and McAleer, 2002a), there are as yet no theoretical results regarding the statistical properties of the model. For GJR(1,1), Ling and McAleer (2002a) 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 $\beta^2 + 2\alpha\beta + 3\alpha^2 + \beta\gamma + 3\alpha\gamma + \frac{3}{2}\gamma^2 < 1$.

An alternative model to capture asymmetric behaviour in the conditional variance is the Exponential GARCH (EGARCH(1,1)) model of Nelson (1991), namely:

$$\log h_t = \omega + \alpha \,|\, \eta_{t-1} \,|\, + \gamma\eta_{t-1} + \beta \log h_{t-1}, \ |\, \beta \,| < 1. \quad (4)$$

There are some distinct differences between EGARCH and the previous two GARCH models, as follows: (i) EGARCH is a model of the logarithm of the conditional variance, which implies that no restrictions on the parameters are required to ensure $h_t > 0$; (ii) Nelson (1991) showed that $|\beta| < 1$ ensures stationarity and ergodicity for EGARCH(1,1); (iii) Shephard (1996) observed that $|\beta| < 1$ is likely to be a sufficient condition for consistency of QMLE for EGARCH(1,1); (iv) as the conditional (or standardized) shocks appear in equation (4), it is likely that $|\beta| < 1$ is a sufficient condition for the existence of all moments, and hence also sufficient for asymptotic normality of the QMLE of EGARCH(1,1).

Furthermore, EGARCH captures asymmetries differently from GJR. The parameters α and γ in EGARCH(1,1) represent the magnitude (or size) and sign effects of the conditional (or standardized) shocks, respectively, on the conditional variance. However, α and $\alpha + \gamma$ represent the effects of positive and negative shocks, respectively, on the conditional variance in GJR(1,1).

As GARCH is nested within GJR, a standard asymptotic test of $H_0 : \gamma = 0$ can be used to discriminate between the two models. However, as EGARCH is non-nested with regard to both GARCH and GJR, the non-nested models are not directly comparable. Ling and McAleer (2000) proposed a simple non-nested test to discriminate between GARCH and EGARCH. Denoting GARCH as the null hypothesis and EGARCH as the alternative, the optimal test statistic for $H_{GARCH} : \delta = 0$ is given by:

$$h_t = w + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1} + \delta\hat{g}_t \quad (5)$$

where $\hat{g}_t$ is the generated one-period ahead conditional variance of EGARCH. For the reverse case, that is, denoting EGARCH as the null hypothesis and GARCH as the alternative, the optimal test statistic for $H_{EGARCH} : \delta = 0$ is given by:

$$\log g_t = w + \alpha \,|\, \eta_{t-1} \,|\, + \gamma\eta_{t-1} + \beta \log g_{t-1} + \delta \log \hat{h}_t \quad (6)$$

where $\hat{h}_t$ is the generated one-period ahead conditional variance of GARCH. Ling and McAleer (2000) showed that the QMLE of δ in both (1), (2) and (5) and (1), (2) and (6) are asymptotically normal under the respective null hypotheses, and consistent under the respective alternative hypotheses. They also derived the power functions of both test statistics under the respective hypotheses.

It is also possible to develop non-nested tests to discriminate between EGARCH and GJR using a similar approach to the above. If EGARCH is the null hypothesis and GJR the alternative, the test statistic for $H_{EGARCH} : \delta = 0$ is given by:

$$\log g_t = w + \alpha \,|\, \eta_{t-1} \,|\, + \gamma\eta_{t-1} + \beta \log g_{t-1} + \delta \log \hat{f}_t \quad (7)$$

where $\hat{f}_t$ is the generated one-period ahead conditional variance of GJR. Similarly, when GJR is the null hypothesis and EGARCH the alternative, the test statistic for $H_{GJR} : \delta = 0$ is given by:

$$f_t = w + \alpha\varepsilon_{t-1}^2 + \gamma D_{t-1}\varepsilon_{t-1}^2 + \beta f_{t-1} + \delta \log \hat{g}_t. \quad (8)$$

It can be shown that the QMLE of δ in both (1), (2) and (7) and (1), (2) and (8) are asymptotically normal under the respective null hypotheses, and consistent under the respective alternative hypotheses.

4. EMPIRICAL RESULTS

4.1 Estimation

This section models the volatility of the patents ratio, or US patents by the top 12 foreign countries relative to total US patents. The AR(1)-GARCH(1,1), AR(1)-GJR(1,1) and AR(1)-EGARCH(1,1) models, as defined in (1)-(2), (1)-(3) and (1)-(4), respectively, are estimated using data for the top 12 foreign countries in the USA. The estimates for the three models are given in Tables 4, 5 and 6, respectively.

4.1.1 AR(1)-GARCH(1,1)

The estimated parameters, and hence conditional volatilities, in Table 4 vary wildly across countries. When the estimates of α and/or β are negative, this will not guarantee that the estimated volatility is positive. However, unless otherwise stated, all models which fail to satisfy the sufficient conditions for $h_t > 0$ in this paper nevertheless yield positive estimates of conditional volatility, as required.

Three countries fail to satisfy the second moment condition for GARCH, namely, France, Korea and Taiwan, although the failure is only marginal for the first two countries. Five countries fail to satisfy the fourth moment condition, namely France, UK, Korea, Sweden and Taiwan, with the result for Taiwan arising from an extremely high estimated α (or short run persistence). Interestingly, all Asian countries have high estimated α values, and relatively low estimated β values, which reflect high levels of short run persistence. The dramatic growth in registered patents in these countries is consistent with the rapid economic growth in Asian countries in the 1980s and 1990s.

Two countries have negative estimates of β, indicating that GARCH may not be an appropriate model. It is interesting to note that the LM test proposed in Engle (1982) and Bollerslev (1986) did not reject the null hypothesis of no GARCH effects, but subsequent results showed that Australia had a significant asymmetric GARCH effect.

Italy also has a negative estimate of β. Thus, even though these two countries satisfy the second and fourth moment conditions, the GARCH model does not seem to be appropriate as it is possible to obtain negative conditional variances. Another interesting feature is that the α and β estimates for other European countries, such as France, Germany, UK, The Netherlands and Sweden, are reasonably similar in magnitude to those in conventional financial time series.

4.1.2 AR(1)-GJR(1,1)

The number of countries failing to satisfy the second moment condition in Table 5 has decreased to three, namely UK, The Netherlands and Taiwan, with only Taiwan being extreme, arising from an excessively high short run persistence in shocks.

As mentioned previously, the LM test failed to reject the null hypothesis of no GARCH effects for Australia. However, under the assumption of normality, the t-statistic for the estimate of γ in the GJR model for Australia is highly significant. Furthermore, the β estimate is now positive, though insignificant, and the α estimate is also statistically insignificant. These results suggest that only negative shocks will have a significant impact on volatility, whereas the impact of positive shocks is minimal. A similar interpretation holds for The Netherlands. Although the estimates of the GARCH model for The Netherlands satisfy the second and fourth moment conditions, the estimates from the more general GJR model fail to satisfy either of the moment conditions. Moreover, the magnitude of the γ estimate is much higher than that of the α estimate. It would seem that negative shocks have far more significant impacts on the conditional variances than do positive shocks.

Furthermore, four countries have negative estimates of γ, namely, France, Italy, Japan and Korea, but only France and Italy fail to satisfy the condition that $\alpha + \gamma > 0$, which implies that the positivity of the conditional variances is not guaranteed. If normality of the estimates is assumed, then the γ estimates are not significant for France and Japan, but are highly significant for Italy and Korea.

The β estimate for Italy is now positive, which implies that the sign of the estimates arising from these models can provide important information regarding model misspecification. This is an interesting area for future research.

4.1.3 AR(1)-EGARCH(1,1)

As shown in Table 6, all the β estimates from EGARCH for all countries are less than one in absolute value, which suggests that all moments exist, with the estimates likely to be consistent and asymptotically normal. There is no restriction on the parameter estimates for conditional volatility to be positive, as EGARCH is a model of the logarithm of the conditional variances.

Overall, the size effects have positive impacts on the conditional variances except in two cases, namely France and Italy. Furthermore, the γ estimates of these two countries, along with Korea, are higher than for the corresponding α estimates. This indicates that the sign effects have larger impacts than size effects on the conditional variances.

It is also important to note that none of the three models is adequate for the UK. Apart from failing the fourth moment condition for GARCH(1,1), as well as the second and fourth moment conditions for GJR(1,1), EGARCH(1,1) does not seem to be identifiable for the UK as the α and γ estimates are not statistically significant. As Engle's (1982) LM test does not reject the null hypothesis of no ARCH effect for the UK, a possible explanation is that there is no ARCH or GARCH effect in the series..

4.2 Model Discrimination

Model discrimination between GARCH and EGARCH and between GJR and EGARCH can be undertaken by using the non-nested testing procedures proposed in Ling and McAleer (2000), and discussed in Section 3 above. Table 7 shows the results of two sets of non-nested tests, namely GARCH versus EGARCH and GJR versus EGARCH.

As shown in Table 7, the test fails to discriminate between GARCH and EGARCH for six countries, namely, France, The Netherlands, Sweden, Switzerland, Taiwan and the UK. Except for Germany, which favours GARCH, EGARCH is favoured for the remaining six countries. Moreover, in discriminating between EGARCH and GJR, EGARCH is favoured for five countries, namely Canada, France, Germany, Japan, and The Netherlands. The non-nested tests, however, fail to discriminate between EGARCH and GJR for the remaining seven countries, which may indicate low power of the test. It is interesting to note that the non-nested tests do not provide strong support for GJR for any of the 12 countries.

It would seem that the best model for both Canada and Japan is EGARCH. However, the non-nested tests did not provide a definitive conclusion regarding the remaining ten countries, which may arise from the presence of outliers in the series. It is important to note that none of the three models was designed to accommodate extreme observations and/or outliers. It is well known that these observations have significant impacts on the QMLE (see for example, Verhoeven and McAleer (1999)), which can subsequently affect the performance of the non-nested tests. Therefore, appropriate methods of accommodating these observations are important in order to apply these tests more efficaciously.

5. CONCLUDING REMARKS

The paper analysed the trends and volatilities in registered US patents for the top 12 foreign patenting countries from 1975 to 1998. The time-varying volatility of the patents ratio, namely US patents lodged by each of the top 12 foreign countries relative to total US patents, was examined using monthly data from the US PTO.

Based on the moment conditions, significance of the estimates and discrimination using non-nested tests, the asymmetric AR(1)-GJR(1,1) model was found to be suitable for Australia, while the best model for Switzerland and The Netherlands was the symmetric AR(1)-GARCH(1,1). An alternative asymmetric model, AR(1)-EGARCH(1,1), was found to be suitable for Canada, France, Germany, Italy, Japan, Korea, Sweden and Taiwan.

Future research might focus on the effects of extreme observations and outliers on the estimates and diagnostic tests of these models. Appropriate methods to accommodate such observations would be helpful in modelling these series more accurately and efficiently.

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Country	US Patents	Patent Intensity*	Ranking by Patent Intensity
1 Japan	429,228	3,405	2
2 Germany	170,875	2,076	4
3 France	72,595	1,233	8
4 Canada	52,354	1,709	5
5 Switzerland	34,684	4,800	1
6 Italy	30,302	527	10
7 Taiwan (China)	28,647	1,313	7
8 Netherlands	24,461	1,558	6
9 Sweden	22,960	2,589	3
10 United Kingdom	22,052	373	12
11 Korea	20,159	433	11
12 Australia	12,734	678	9
US Patents by Top 12	921,051	1,589	
Total US patents	2,397,490	-	
US Patents by Top 12 Relative to Total US Patents	38.4%	-	

Table 1. US Patents and Patent Intensity for Selected Countries, January 1975 – December 1998 (as at 4 April 2002)

* Patent intensity denotes US patents per million of 1998 population

Source of data: http://164.195.100.11/netahtml/search-adv.htm and http://www.census.gov/ipc/www/idbprint.html

Country	Australia	Canada	France	Germany	Italy	Japan	Korea	Netherlands	Sweden	Switzerland	Taiwan	UK
Australia	1.000	0.826	0.775	0.715	0.769	0.801	0.739	0.738	0.661	0.525	0.783	0.784
Canada	0.826	1.000	0.903	0.741	0.844	0.890	0.841	0.877	0.758	0.615	0.887	0.893
France	0.775	0.903	1.000	0.727	0.897	0.851	0.761	0.859	0.718	0.629	0.774	0.788
Germany	0.715	0.741	0.727	1.000	0.747	0.877	0.625	0.722	0.835	0.415	0.685	0.691
Italy	0.769	0.844	0.897	0.747	1.000	0.857	0.694	0.818	0.672	0.527	0.744	0.744
Japan	0.801	0.890	0.851	0.877	0.857	1.000	0.775	0.848	0.750	0.452	0.831	0.806
Korea	0.739	0.841	0.761	0.625	0.694	0.775	1.000	0.785	0.739	0.423	0.926	0.899
Netherlands	0.738	0.877	0.859	0.722	0.818	0.848	0.785	1.000	0.730	0.561	0.789	0.813
Sweden	0.661	0.758	0.718	0.835	0.672	0.750	0.739	0.730	1.000	0.466	0.741	0.787
Switzerland	0.525	0.615	0.629	0.415	0.527	0.452	0.423	0.561	0.466	1.000	0.419	0.492
Taiwan	0.783	0.887	0.774	0.685	0.744	0.831	0.926	0.789	0.741	0.419	1.000	0.957
UK	0.784	0.893	0.788	0.691	0.744	0.806	0.899	0.813	0.787	0.492	0.957	1.000

Table 2. Correlation Coefficients Between the Top 12 Foreign Countries

Country	Total
Australia	0.839
Canada	0.979
France	0.922
Germany	0.762
Italy	0.863
Japan	0.916
Korea	0.864
Netherlands	0.887
Sweden	0.770
Switzerland	0.634
Taiwan	0.899
UK	0.898

Table 3. Correlation Coefficients of the Top 12 Foreign Countries with Total US Patents

Country	ω	α	β	2^{nd} Moment	4^{th} Moment
Australia	2.13E-06 (1.857)	0.065 (0.803)	-0.384 (-0.587)	-0.319	0.110
Canada	7.62E-07 (0.810)	0.052 (1.18)	0.790 (3.641)	0.842	0.714
France	-1.63E-07 (-4.043)	0.028 (6.20)	0.981 (14.776)	1.008	1.018
Germany	1.50E-06 (0.429)	0.052 (0.50)	0.923 (6.025)	0.975	0.956
Italy	1.00E-05 (11.162)	0.128 (4.76)	-0.906 (-20.949)	-0.778	0.638
Japan	0.000112 (1.818)	0.332 (2.362)	0.445 (2.110)	0.776	0.822
Korea	2.37E-07 (0.873)	0.313 (1.632)	0.691 (4.798)	1.004	1.205
Netherlands	1.01E-08 (0.255)	0.051 (1.96)	0.944 (29.613)	0.995	0.996
Sweden	1.02E-07 (0.431)	0.119 (0.783)	0.868 (5.405)	0.986	1.001
Switzerland	2.95E-08 (0.737)	0.052 (3.06)	0.937 (44.033)	0.990	0.985
Taiwan	2.73E-09 (2.139)	0.758 (5.79)	0.526 (9.067)	1.284	2.795
UK	2.59E-08 (0.748)	0.146 (1.096)	0.849 (7.073)	0.995	1.034

Table 4. GARCH(1,1) Estimates for the Top 12 Foreign Countries (t-ratios are in parentheses)

Country	ω	α	γ	β	2^{nd} Moment	4^{th} Moment
Australia	1.31E-06 (3.359)	0.001 (0.0122)	0.408 (2.323)	0.035 (0.171)	0.240	0.141
Canada	1.76E-06 (2.881)	-0.084 (-5.700)	0.269 (2.636)	0.594 (3.808)	0.644	0.420
France	1.31E-06 (1.555)	0.086 (1.328)	-0.140 (-1.739)	0.869 (11.157)	0.884	0.783
Germany	3.415E-05 (0.496)	0.146 (0.424)	0.034 (0.0619)	0.623 (0.918)	0.785	0.669
Italy	6.36E-07 (2.152)	0.097 (2.160)	-0.183 (-3.130)	0.862 (13.985)	0.868	0.754
Japan	1.51E-05 (1.677)	0.265 (3.385)	-0.064 (-0.668)	0.698 (8.561)	0.932	0.976
Korea	1.04E-07 (3.237)	0.394 (5.271)	-0.574 (-6.063)	0.843 (27.670)	0.951	0.927
Netherlands	-3.98E-08 (-3.743)	0.001 (0.601)	0.032 (4.174)	0.999 (40.774)	1.015	1.031
Sweden	5.14E-08 (0.349)	0.0920 (0.640)	0.0008 (0.00462)	0.9006 (7.381)	0.9930	1.0031
Switzerland	1.49E-08 (0.349)	0.030 (1.270)	0.037 (1.171)	0.947 (39.758)	0.996	0.996
Taiwan	2.76E-09 (2.147)	0.735 (3.766)	0.040 (0.155)	0.527 (9.011)	1.282	2.785
UK	1.399E-08 (0.587)	0.173 (0.128)	0.099 (0.278)	0.822 (6.429)	1.044	1.187

Table 5. GJR(1,1) Estimates for the Top 12 Foreign Countries (t-ratios are in parentheses)

Country	ω	α	γ	β
Australia	-4.316	0.128	-0.048	0.684
	(-0.647)	(0.852)	(-0.859)	(1.381)
Canada	-22.291	0.194	-0.052	-0.806
	(-14.509)	(2.014)	(-0.857)	(-6.172)
France	-6.651	-0.105	0.273	0.406
	(-2.825)	(-0.810)	(3.387)	(1.946)
Germany	-15.644	0.526	-0.010	-0.546
	(-10.553)	(3.059)	(-0.191)	(-3.517)
Italy	-3.155	-0.203	0.373	0.731
	(-4.049)	(-2.277)	(4.819)	(10.735)
Japan	-2.627	0.584	0.081	0.754
	(-3.114)	(6.241)	(1.272)	(7.990)
Korea	-8.719	0.0252	0.0976	0.2817
	(-22.383)	(2.205)	(9.947)	(7.926)
Netherlands	-0.353	0.107	0.021	0.979
	(-0.796)	(1.849)	(0.509)	(29.281)
Sweden	-5.027	0.478	0.237	0.632
	(-2.487)	(2.940)	(2.492)	(4.040)
Switzerland	-6.454	0.410	-0.232	0.514
	(-2.538)	(3.362)	(-2.652)	(2.554)
Taiwan	-3.871	1.140	-0.078	0.768
	(-11.004)	(8.354)	(-0.727)	(27.183)
UK	-8.301	0.103	0.006	0.363
	(-2.090)	(1.864)	(0.806)	(59.412)

Table 6. EGARCH(1,1) Estimates for the Top 12 Foreign Countries (t-ratios are in parentheses)

Country	H_0 : GARCH H_A : EGARCH	H_0 : EGARCH H_A : GARCH	H_0 : EGARCH H_A : GJR	H_0 : GJR H_A : EGARCH
Australia	2.4658	0.3068	0.5797	-1.8668
Canada	8.3346	0.0686	0.4668	5.5633
France	2.8839	3.2900	0.7849	8.6868
Germany	0.6332	3.8912	1.7944	13.3718
Italy	6.1631	0.2263	2.5292	5.6725
Japan	5.8698	0.1864	0.0861	3.6386
Korea	2.9693	0.5817	2.3410	3.5734
Netherlands	2.1601	2.4631	1.9274	2.2969
Sweden	4.2916	2.3712	2.5406	5.0537
Switzerland	2.0703	5.3307	5.6900	11.4745
Taiwan	5.9372	3.3539	3.6908	7.7450
UK	4.1017	13.1239	10.9485	9.2034

Table 7. Non-nested Tests of GARCH versus EGARCH and GJR versus EGARCH (the entries in columns 2-5 are the calculated t-ratios from equations (5)-(8), respectively).

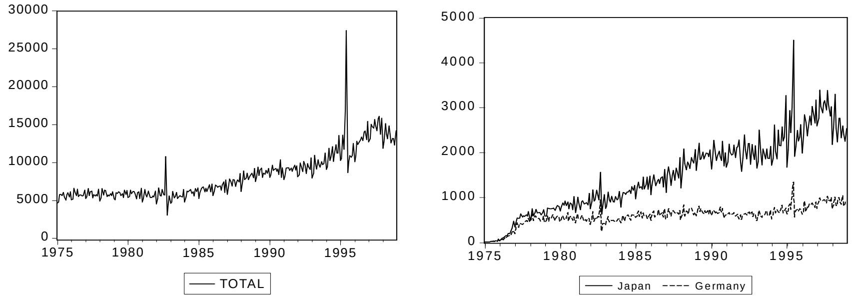

Figure 1. Total US Patents and US Patents held by Japan and Germany, by Date of Application, 1975-1998

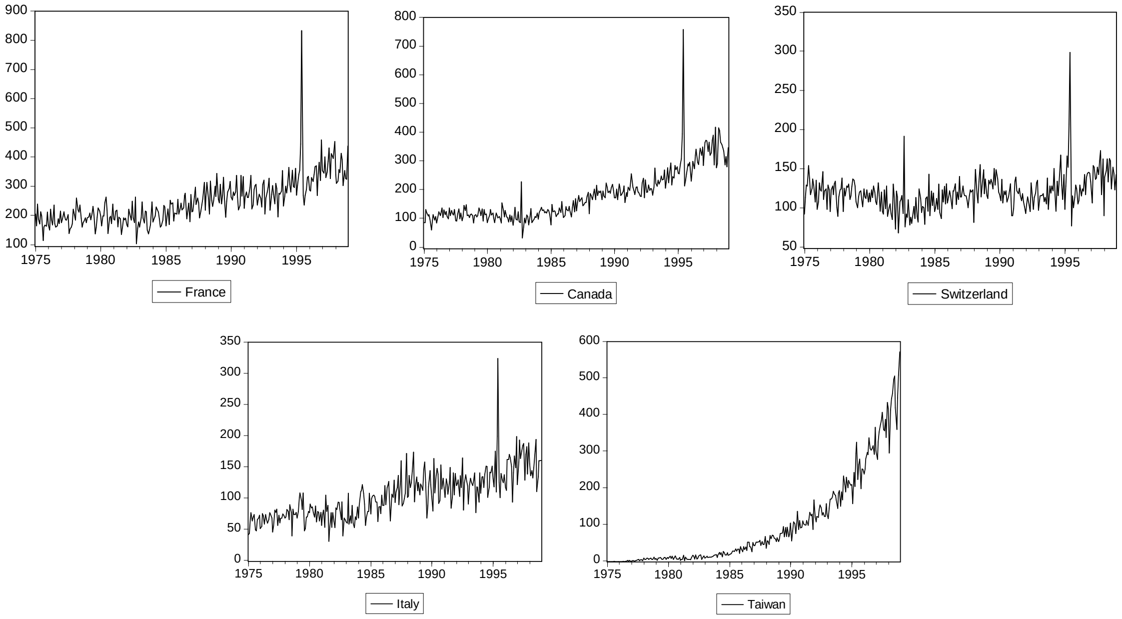

Figure 2. US Patents held by France, Canada, Switzerland, Italy and Taiwan, by Date of Application, 1975-1998

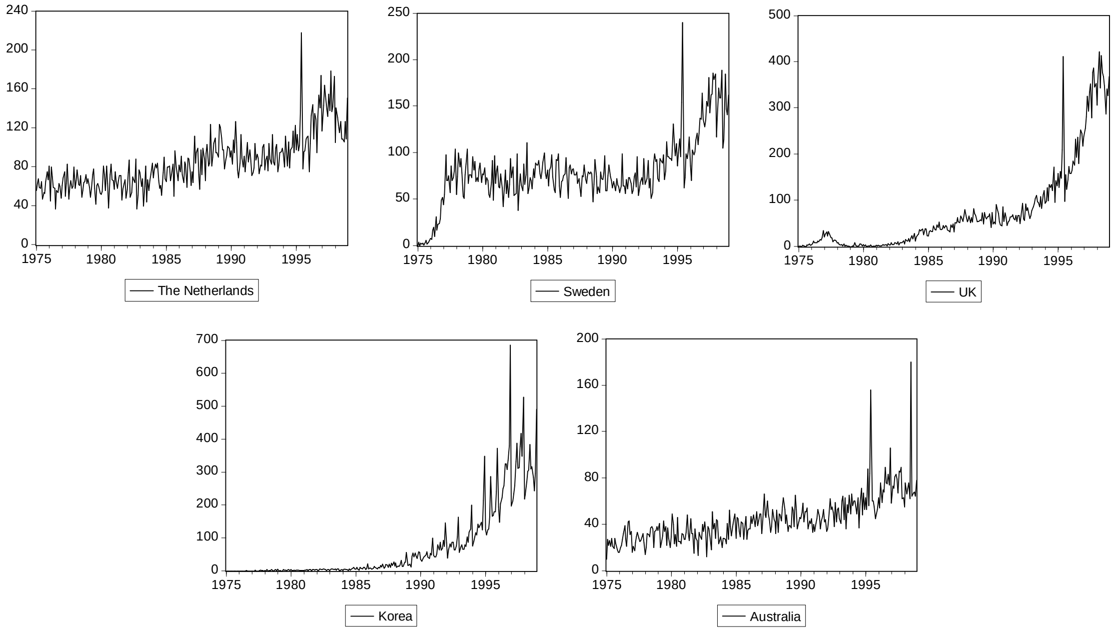

Figure 3. US Patents held by The Netherlands, Sweden, UK, Korea and Australia, by Date of Application, 1975-1998

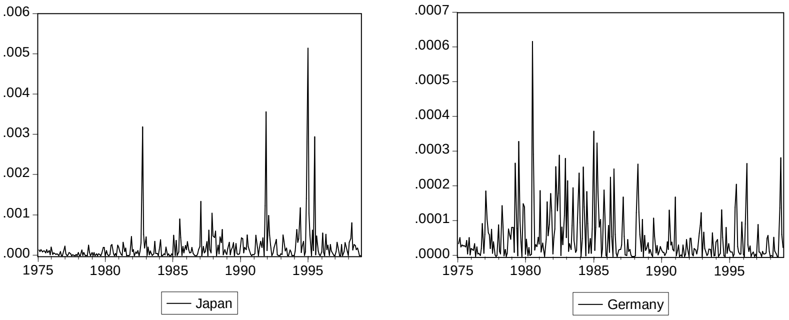

Figure 4. Volatility of US Patents Ratios of Japan and Germany, by Date of Application, 1975-1998

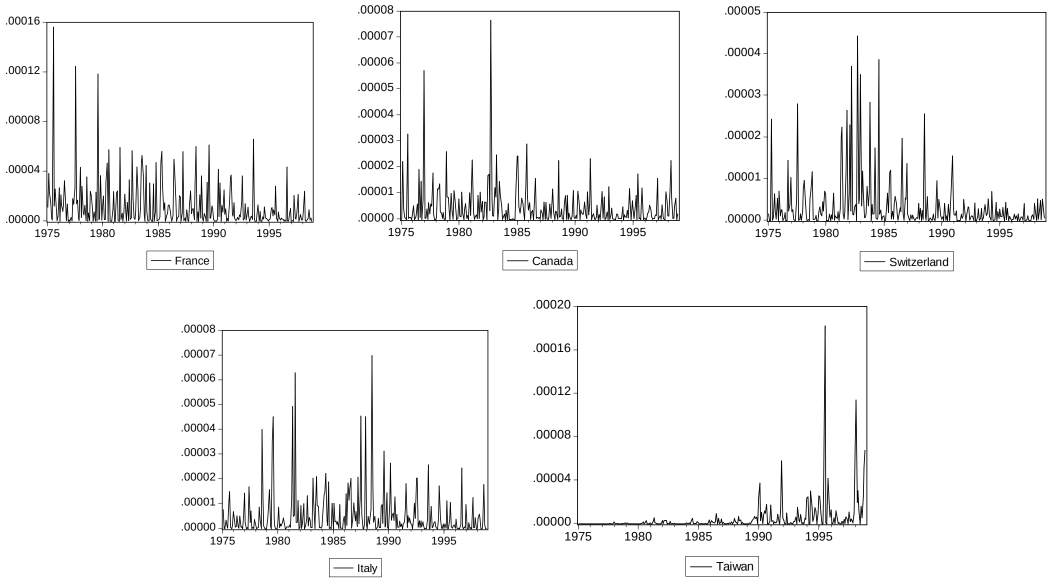

Figure 5. Volatility of US Patents Ratios of France, Canada, Switzerland, Italy and Taiwan, by Date of Application, 1975-1998

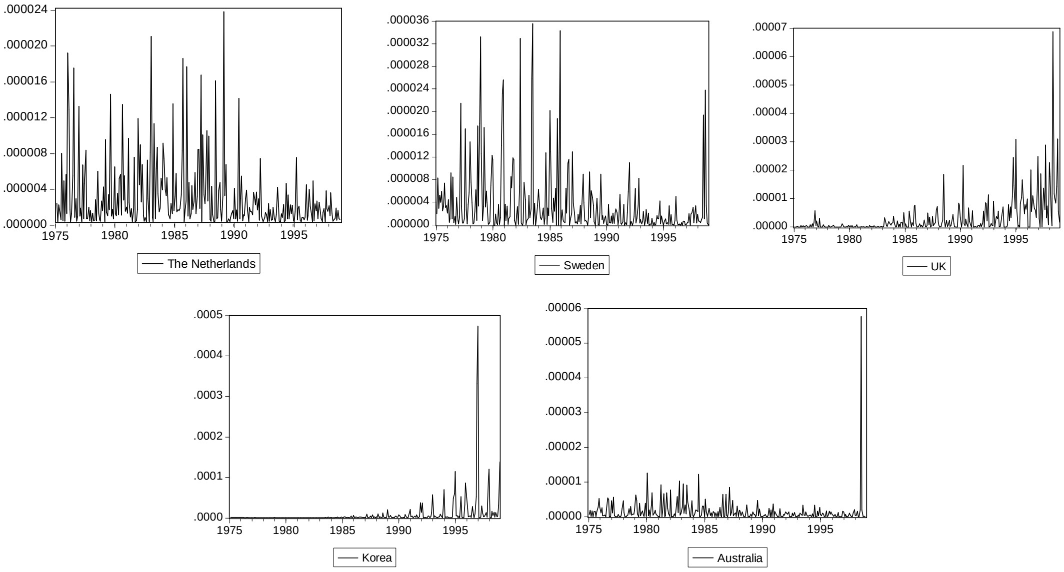

Figure 6. Volatility of US Patents Ratios of The Netherlands, Sweden, UK, Korea and Australia, by Date of Application, 1975-1998