Rolling Conditional Correlations of Foreign Patents in the USA

Felix Chan
Dora Marinova
Michael McAleer

Follow this and additional works at: https://scholarsarchive.byu.edu/iemssconference

Chan, Felix; Marinova, Dora; and McAleer, Michael, "Rolling Conditional Correlations of Foreign Patents in the USA" (2004). International Congress on Environmental Modelling and Software. 92. https://scholarsarchive.byu.edu/iemssconference/2004/all/92

This Event is brought to you for free and open access by the Civil and Environmental Engineering at BYU ScholarsArchive. It has been accepted for inclusion in International Congress on Environmental Modelling and Software by an authorized administrator of BYU ScholarsArchive. For more information, please contact scholarsarchive@byu.edu, ellen_amatangelo@byu.edu.
Rolling Conditional Correlations of Foreign Patents in the USA

Felix Chan, Dora Marinova and Michael McAleer

1 School of Economics and Commerce, University of Western Australia (Felix.Chan@uwa.edu.au)
2 Institute for Sustainability and Technology Policy, Murdoch University
3 School of Economics and Commerce, University of Western Australia

Abstract: Patent registrations have often been used as a proxy of innovation as they reflect a country’s technological capability. Recently, some studies have found that the Generalised Autoregressive Conditional Heteroscedasticity (GARCH) model and an asymmetric extension, namely Glosten, Jagannathan and Runkle’s (GJR) model, are useful to model the time-varying volatility of the patent ratio, namely the ratio of foreign patents registered in the USA to total patents in the USA. However, this approach assumes that the conditional variance is independent across countries. Furthermore, the time series properties of the patent growth rate, namely the rate of change of foreign patents registered in the USA, have not previously been analysed. This paper examines the conditional variance of the patent growth rate from the leading four foreign countries, namely Canada, France, Germany and Japan, using the Constant Conditional Correlation – Multivariate GARCH (CCC-MGARCH), Vector Autoregressive Moving Average – GARCH (VARMA-GARCH) and VARMA – Asymmetric GARCH (VARMA-AGARCH) models. The results reveal the existence of cross-countries effects in the patent growth rate among the leading four countries, as well as asymmetric effects using monthly data from January 1975 to December 1998. Rolling estimates show that the restrictive assumption of constant conditional correlation is unlikely to hold, and models that accommodate dynamic conditional correlations may provide greater insights for investigating the effects of global factors on changes in innovation for the four leading foreign countries.

Keywords: Patent ratio, Patent growth rate, GARCH, Multivariate GARCH, Asymmetries.

1. Introduction

Patent registrations have often been used as a proxy for innovation, and are used to describe a country’s technological capabilities. Some examples can be found in Pavitt (1988), Patel and Pavitt (1995), Griliches (1990) and Marinova (2001). Since the USA has the world’s largest economy, it is not surprising that innovative America and foreign companies include the USA as a primary destination for registering patents. Therefore, the trends in technological strength and market ambitions can be examined by analysing the patents registered at the US Patent and Trademark Office (PTO). However, the time series properties of patent registrations have not been investigated in detail until recently.

The success of Engle’s (1982) Autoregressive Conditional Heteroscedasticity (ARCH) model to capture time-varying volatility provides a convenient framework to investigate time-varying conditional variance (or risk). Numerous extensions of ARCH have been investigated in the last two decades to capture various aspects of time-varying conditional variances and covariances. In particular, Bollerslev’s (1986) Generalised Autoregressive Conditional Heteroscedasticity (GARCH) model, Glosten, Jagannathan and Runkle (1992) (GJR) asymmetric model, and Nelson’s (1991) Exponential GARCH (EGARCH) model have been shown to be useful in modelling the conditional variance in the patent ratio, namely the ratio of foreign patents registered in the USA to total patents registered in USA. For example, the time-varying nature of volatility in the patent ratio was analysed extensively in McAleer, Chan and Marinova (2002) at the univariate level. Moreover, Marinova and McAleer (2003) investigated the conditional variance of the ecological patent ratio, or the ratio of ecological patents registered in the USA to total patents registered in the USA, while Chan, Marinova and McAleer (2003) investigated the volatility of the Japanese electronic patent ratio, or the ratio of Japanese electronic patents registered in the USA to total electronic patents registered in the USA. Furthermore, Chan, Marinova and McAleer (2004) modelled the conditional mean and conditional variance of US ecological patents using a family of regime-switching models.

However, these studies modelled the conditional variances at the univariate level, which assumes independence in the conditional variances across countries and/or industries. This assumption may not be reasonable as innovation is often the result of accumulating knowledge and technical know-how across countries and industries. Therefore, previous innovations from other countries and industries are also likely to be important in determining future inventions. Moreover, the studies mentioned above
have focused primarily on the volatility of the patent ratio, whereas the conditional volatility of the rate of change of patent registrations, or the patent growth rate, has not yet been investigated in the literature.

This paper models the conditional volatility of the rate of change, or patent growth rate, of patents registered in the USA from the four leading foreign countries, namely Canada, France, Germany and Japan, using the Constant Conditional Correlation – Multivariate GARCH (CCC-MGARCH) model of Bollerslev (1990), the Vector Autoregressive Moving Average – GARCH (VARMA-GARCH) model of Ling and McAleer (2003), and the VARMA – Asymmetric GARCH (VARMA-AGARCH) model of Chan, Hoti and McAleer (2002), using monthly date for the USA from January 1975 to December 1998.

As the structural and statistical properties of these multivariate models have been established, the existence of interdependent (or cross-country) and asymmetric effects can be formally tested. The results support the existence of interdependent effects, that is, the conditional variance of the patent growth rate of one country is affected by other countries. Asymmetric effects, which differentiate between the impacts of positive and negative shocks, are also found to be significant.

Furthermore, the three multivariate GARCH models assume that the conditional correlation of the standardized shocks between country pairs is constant over time. Rolling conditional correlations are estimated to examine the validity of this assumption. The results provide evidence against constant conditional correlation for each of the three models.

The plan of the remainder of the paper is as follows: Section 2 provides a qualitative description of the data used in the paper. Section 3 presents the three constant conditional correlation multivariate GARCH models, as well as their structural and statistical properties. Section 4 reports the empirical results and the dynamic paths of the rolling conditional correlation estimates. Section 5 provides some concluding remarks.

2. Data

The monthly data used in this paper were extracted from the official Internet Webpage of the US PTO, and include all granted patents with date of lodged applications between January 1975 and December 1998, with a total of 288 observations per country. The reason for using the date of lodgment of granted applications rather than the date of issue of patent is to avoid organizational delays as it takes an average of three to five years for a patent to be officially issued.

Overall, the number of patents registered in the USA from the four leading foreign countries has grown steadily over the last two decades. Moreover, the number of patents registered in the USA from Germany grew rapidly in the late 1970s, but slowed in the early 1980s and remained steady for the rest of the sample. According to McAleer, Chan and Marinova (2002), Japan was ranked first in terms of the total number of patents registered in the USA between January 1975 and December 1998 with 429,228 patents. Germany was ranked second with a total of 170,875 patents, France third with 72,595 patents, and Canada fourth with 52,354 patents. Interestingly, all four countries seem to have experienced an outlier in the early 1990s.

All four countries have outliers in the patent growth rate between October 1982 and July 1995. Furthermore, Japan has two additional outliers, namely a positive outlier in October 1982 when the patent growth rate increased substantially from 0.225 to 2.210, followed by a negative outlier in November 1992, when the patent growth rate decreased dramatically from 2.210 to –2.373.

Japan has the highest average patent growth rate at 1.8%, followed closely by Germany at 1.4%, and distantly by Canada at 0.5% and France at 0.3%. Not surprisingly, the ranking based on the highest average growth rate is the same as that based on the total number of registered patents. The growth rate of US patent registrations by Japan is also the most volatile, based on the standard deviation of 0.282, followed closely by Canada with 0.237, France with 0.212, and finally Germany with 0.194. Moreover, all four countries are negatively skewed, particularly Canada, and exhibit excessive kurtosis.

While the volatility of the patent growth rate for the four leading foreign countries is relatively low, on average, all seem to have two outliers in October 1982 and July 1995, as discussed previously. Moreover, Japan has two unique outliers in the patent growth rate in October 1992 and December 1992, which could also be detected from its volatility. Volatility clustering is also common in the patent growth rates for the four countries, such that a large shock tends to be followed by another large shock. The presence of volatility clustering, together with excessive kurtosis, would also seem to suggest a non-constant conditional variance in the patent growth rate for all four countries.

The Phillips-Perron (1988) (PP) test statistics for non-stationarity and the ARCH test statistics for conditional heteroskedasticity were calculated. The conventional Augmented Dickey-Fuller (ADF) test for non-stationarity assumes that the disturbances are independently and identically distributed (iid). As the patent growth rate is likely to follow a GARCH process, the iid assumption is not likely to be valid, and the PP test has been shown to be more powerful in the presence of heteroscedasticity and serial correlation under a wide range of circumstances.
(Phillips and Perron (1988)). Therefore, the PP test is likely to be more appropriate than the conventional ADF test in this case.

The PP test statistics are significant at the 1% level, indicating that the patent growth rates for all four countries are stationary. Moreover, the ARCH test statistics reject the null hypothesis of no ARCH effects, thereby suggesting that the GARCH model is appropriate for capturing the dynamics in the conditional variance of patent growth rates for the four leading foreign countries.

In this paper, three multivariate GARCH models will be used to capture the dynamics in the conditional variance of the four countries. The specification, structural and statistical properties of the three constant conditional correlation multivariate volatility models are presented in the next section. An important characteristic of these three models is that the structural and statistical properties are known, which allows valid inferences to be conducted. In particular, it allows cross-countries effects, as well as asymmetric effects, to be tested.

3. Models

The purpose of the remainder of the paper is to model the volatility of the patent growth rate in the USA from the top four foreign countries. The estimated models include the Constant Conditional Correlation Multivariate GARCH (CCC-MGARCH) model of Bollerslev (1990), Vector Autoregressive Moving Average – GARCH (VARMA-GARCH) model of Ling and McAleer (2003), and VARMA – Asymmetric GARCH (VARMA-AGARCH) model of Chan, Hoti and McAleer (2002). The specification, structural and statistical properties of these models will be discussed in this section.

Consider the following specification:

\[ y_t = E(y_t | F_{t-1}) + \epsilon_t \]
\[ \epsilon_t = D_t \eta_t, \]

where \( y_t = (y_{1t},...,y_{mt})' \), \( \eta_t = (\eta_{1t},...,\eta_{mt})' \) is a sequence of independently and identically distributed (iid) random vectors, and \( D_t = \text{diag}(h_{1t}^{1/2},...,h_{mt}^{1/2}) \). Bollerslev (1990) assume the conditional variance for each asset, \( h_{it}, i=1,...,m \), follows a univariate GARCH process, that is,

\[ h_{it} = \omega_i + \sum_{j=1}^r \alpha_j \epsilon_{it-j}^2 + \sum_{j=1}^s \beta_j h_{i,t-j} \]

where \( \alpha_j \) represents the ARCH effects, or the short run persistence of shocks, and \( \beta_j \) represents the GARCH effects, or the contribution of shocks to long run persistence, namely \( \sum_{j=1}^r \alpha_j + \sum_{j=1}^s \beta_j \).

Although this specification has a computational advantage over other multivariate GARCH models, such as the BEKK model of Engle and Kroner (1995), it assumes independence of the conditional variances across countries. In order to accommodate possible interdependencies, Ling and McAleer (2003) proposed the following specification for the conditional variance:

\[ H_i = W + \sum_{j=1}^r A_{ij} \epsilon_{i,t-j} + \sum_{j=1}^s B_{ij} H_{i,t-j} \]

where \( H_i = (h_{1i},...,h_{mi})' \), \( \epsilon_t = (\epsilon_{1t},...,\epsilon_{mt})' \), and \( W \), \( A_i \forall i = 1,...,r \) and \( B_j \forall j = 1,...,s \) are \( m \times m \) matrices. As in the univariate GARCH model, VARMA-GARCH assumes that negative and positive shocks have identical impacts on the conditional variance. In order to accommodate asymmetric impacts of positive and negative shocks, Chan, Hoti and McAleer (2002) proposed the following specification for the conditional variance:

\[ H_i = W + \sum_{j=1}^r A_{ij} \epsilon_{i,t-j} + \sum_{j=1}^s C_{ij} \epsilon_{i,t-j} + \sum_{j=1}^s B_{ij} H_{i,t-j} \]

where \( C_i \) are \( m \times m \) matrices for \( i = 1,...,r \), and \( I_i = \text{diag}(I_{1i},...,I_{mi}) \), so that

\[ I_i = \begin{cases} 0, & \epsilon_{it} \geq 0 \\ 1, & \epsilon_{it} < 0 \end{cases} \]

VARMA-AGARCH reduces to VARMA-GARCH when \( C_i = 0 \) for all i. Furthermore, if \( C_i = 0 \), with \( A_i \) and \( B_j \) being diagonal matrices for all \( i, j \), then VARMA-AGARCH reduces to CCC-MGARCH. Therefore, CCC-MGARCH and VARMA-GARCH are both nested within VARMA-AGARCH. The structural and statistical properties of VARMA-GARCH were established in Ling and McAleer (2003). This includes the necessary and sufficient conditions for stationarity and ergodicity, sufficient conditions for the existence of moments of \( \epsilon_t \), and sufficient conditions for consistency and asymptotic normality of the Quasi-Maximum Likelihood Estimators (QMLE) in the absence of normality of \( \eta_t \). As CCC-MGARCH is nested within VARMA-GARCH, the structural and statistical properties established in Ling and McAleer (2003) also apply to CCC-MGARCH.

As an extension of VARMA-GARCH, the structural and statistical properties of VARMA-AGARCH were established in Chan, Hoti and McAleer (2002). As in the case of VARMA-GARCH, the necessary and sufficient conditions for stationarity and ergodicity, the sufficient conditions for the existence of moments of \( \epsilon_t \), and sufficient conditions for consistency and asymptotic normality of the QMLE, were also
established. It follows that the conditions established for VARMA-AGARCH in Chan, Hoti and McAleer (2002) are equivalent to those for VARMA-GARCH in Ling and McAleer (2003) when $C_i = 0$ for all $i$.

It is important to note that the conditional correlation is assumed to be constant for all three models. From model (1), it is obvious that

$$\varepsilon_t = D_t \eta_t D_t^{-1}$$

and, as $\eta_t$ is a sequence of iid random vectors, the conditional covariance matrix is

$$E(\varepsilon_t \varepsilon_t') = \Omega_t = D_t \Gamma D_t^{-1}$$

where $\Gamma = E(\eta_t \eta_t' | F_{t-1}) = E(\eta_t \eta_t')$, which is a constant matrix for all $t$. The conditional correlation matrix is then defined as

$$\Gamma = D_t' \Omega_t D_t^{-1}$$

which is assumed to be constant over time. Furthermore, the conditional correlation matrix of $\varepsilon_t$ is, by definition, equal to the covariance matrix of the standardised shocks, $\eta_t$.

Unless $\eta_t$ is a sequence of iid random vectors, the assumption of constant conditional correlation will not be valid. In order to capture the dynamics of time-varying conditional correlation, Engle (2002) and Tse and Tsui (2002) proposed the Dynamic Conditional Correlation (DCC) model and the Variable Conditional Correlation Multivariate GARCH model, respectively. Chan, Hoti and McAleer (2003) proposed the Generalized Autoregressive Conditional Correlation (GARCC) model, which has both DCC and VCC-MGARCH as special cases. They showed that, if $\eta_t$ follows an autoregressive process with stochastic coefficients, then model (1)-(2) is equivalent to Engle’s (2002) DCC model. Chan, Hoti and McAleer (2003) also established the structural and statistical properties of GARCC, which includes the necessary and sufficient conditions for stationarity and ergodicity, sufficient conditions for the existence of moments, and sufficient conditions for the consistency and asymptotic normality of the QMLE.

In the next section, models (1)-(2), (1)-(3) and (1)-(4) will first be estimated under the assumption of constant conditional correlation. This assumption will then be evaluated using rolling regressions.

4. Empirical Results

This section models the conditional variance of the patent growth rate of the four leading foreign countries, namely Canada, France, Germany and Japan, using CCC-MGARCH, VARMA-GARCH and VARMA-AGARCH. The conditional mean is assumed to follow an AR(1) process, with $r = s = 1$ for each country. The parameter estimates for the three models and their asymptotic t-ratios are available on request. The asymptotic results presented in the previous section facilitate the subsequent hypothesis testing for the three models used in this section.

The ARCH $\alpha$ effects are significant for all four countries, but the GARCH $\beta$ effects are significant only for Germany and Japan. Canada exhibits high short run persistence at 0.518, while the ARCH effects are relatively lower for France, Germany and Japan. Moreover, Germany has the highest long run persistence, $\alpha + \beta$, at 0.888.

The negative asymmetric effect, $\gamma$, is significant for France, Germany and Japan, but not for Canada. Moreover, $\gamma$ is negative for all four countries, implying that negative shocks reduce the conditional variance in the patent growth rate. A positive shock in the patent growth rate can be viewed as an indication of a technological breakthrough or a factor that would encourage subsequent research activities, and hence would increase the uncertainty in the patent growth rate. On the contrary, a negative shock indicates a decline in the growth rate, and hence in future research activities, so that the patent growth rate would become less volatile.

In terms of interdependencies across different countries, the conditional variance of Canada is affected by its previous long run shock, as well as previous long run shocks from France and previous short run shocks from Germany and Japan. The conditional variance of France is affected by previous short and long run shocks, as well as previous short run shocks from Canada, and previous short and long run shocks from Japan. Moreover, the conditional variance of Germany is affected by previous short run shocks from Canada, as well as previous short and long run shocks from Japan. Finally, the conditional variance of Japan is affected by previous short and long run shocks, as well as the short and long run shocks from France.

Interestingly, VARMA-GARCH and VARMA-AGARCH provide the same cross-country effects for Canada, for which the asymmetric effects are not significant. However, the cross-country effects given by the two models can be different when the asymmetric effects are significant. This could be due to model misspecification or the small sample properties of the QMLE for multivariate GARCH models, and is an interesting area for future research.

The conditional correlations between the four countries from the three models are very similar. The conditional correlations are generally quite high, indicating a strong positive relationship between the standardised shocks of the four countries. Therefore,
all four countries seem to share a substantial amount of common shocks, which is not surprising as all four countries share at least two common outliers in October 1982 and July 1995.

However, all three models assume that the conditional correlations are constant over time. In order to check the validity of this assumption, rolling conditional correlations are estimated with a window size set to 200.

The dynamic paths of the conditional correlations are very similar for the three models. Overall, the conditional correlations for the country pairs (Canada, Germany), (Canada, France) and (France, Germany) exhibit upward trends until 1979, which indicate increasing conditional correlations between the standardised shocks. Interestingly, in the case of (Canada, France), the conditional correlation begins to decrease after 1979, while the conditional correlations for (Canada, Germany) and (France, Germany) remain steady after 1979.

Furthermore, in the case of (Canada, Japan), (Germany, Japan) and (France, Japan), the conditional correlations generally begin at a relatively high level, then decrease substantially in March 1976. The dramatic decrease in the conditional correlations between Japan and the other three countries is due mainly to the inclusion of the outlier in December 1992, which is unique to Japan. Interestingly, the conditional correlations of (France, Japan) and (Canada, Japan) seem to increase after March 1976 to their initial levels. However, the conditional correlations of (Germany, Japan) remain low for the remaining samples.

The high positive conditional correlations between the four leading foreign countries suggest that positive (negative) shocks in one country will simultaneously impact positively (negatively) on other countries. An alternative interpretation of these results is that the patent growth rates of these countries are determined, at least in part, by some common factors such as global economic performance and market competition. Any changes in these common factors will, therefore, have an impact on all four countries simultaneously. However, the rolling conditional correlation estimates also suggest that the conditional correlations may not be constant over time, which reflects the existence of unique factors that may affect each country independently. The outlier in Japan in December 1992 is a clear example of such a phenomenon.

5. Concluding Remarks

This paper analysed the conditional volatility of the patent growth rate for the four leading foreign countries, that is, the rate of change of patents registered in the USA from Canada, France, Germany and Japan. The CCC-MGARCH, VARMA-GARCH

and VARMA-AGARCH models were estimated to capture the dynamics of the conditional variance in the patent growth rate using monthly data from January 1975 to December 1998. The empirical results provided evidence to support the presence of interdependent effects in the conditional variance of the patent growth rate between the four leading foreign countries. Moreover, the results also revealed the presence of significant asymmetric effects in France, Germany and Japan, which suggested that positive shocks have an impact on the conditional variance which is different from negative shocks in these countries. Therefore, VARMA-AGARCH is superior to both CCC-MGARCH and VARMA-GARCH for modelling the conditional variance of the patent growth rate of the four leading foreign countries.

The conditional correlations for the three models were also estimated. In common with related results in the finance and financial econometrics literature, the conditional correlations for the three models were not substantially different from one other. However, the conditional correlations in all cases were relatively high, thereby suggesting the presence of strong global factors determining the patent growth rates in all four countries.

Rolling conditional correlation estimates revealed that the conditional correlations were unlikely to be constant over time. Therefore, models that accommodate dynamic conditional correlation, such as the DCC model of Engle (2002) and the GARCC model of Chan, Hoti and McAleer (2003) may provide greater insights for investigating the effects of global factors on changes in innovation for the four leading foreign countries.

6. Acknowledgements

The first author wishes to acknowledge the financial support of an Australian Postgraduate Award and an Individual Research Grant at the University of Western Australia, the second author is most grateful for the financial support of the Australian Research Council and the Department of Economics at the University of Western Australia, and the third author gratefully acknowledges the financial support of the Australian Research Council.

7. References


Chan F., S. Hoti and M. McAleer (2002), Structure


Chan, F., D. Marinova and M. McAleer (2003), Modelling the asymmetric volatility of electronics patents in the USA, to appear in *Mathematics and Computers in Simulation*.


