**Introduction**

The paper examines the effect of research and development spending on the number of patents applied and granted within the year. This paper explores both the impact of current and previous years’ effect of research and development spending on patents. Data for analysis include information on 643 manufacturing firm from the year 1972 to 1979. In analysing these effects, the random effect panel regression, the panel Poisson random effect model and the panel Negative Binomial model were employed. In all cases, there exists significant positive effect of current and previous years’ research and development on patents.

**Panel Specification**

The panel data used in the study comprises information on 643 manufacturing firm entities over the period of years from 1972 to 1979. The individual-specific effect is modelled as

where connotes the unobserved intercept and represent the slope parameters of the explanatory variables. A random effect specification is specified if is random whereas a fixed effect model is specified if is fixed . The paper focuses on the random effect model because it produces overall significance in estimation.

Due to the nature of the dependent variable, which is nonnegative discrete count variable, both the panel Poisson random effects and the panel negative binomial effects models are examined. In later sections of the paper, the paper would explore characteristics of the data and modelling which shown that panel versions of the Poisson and the negative binomial effects models performed better than the cross-sectional versions of same including zero-inflated models.

**Panel Poisson Random Effects Model**

The panel Poisson random effects can be modelled using the following from the panel specifications above.

where is assumed to be Gamma distributed, unobserved but not correlated with the explanatory variables.

**Panel Negative Binomial Random Effects Model**

The data can be estimated using panel Negative Binomial random effects model when the following hold.

where is assumed to be Beta distributed, unobserved but not correlated with the explanatory variables.

In both the cases of the panel Poisson and negative binomial random effect model, population-averaged specifications were analysed.

**Equation Specification**

The following equations were estimated each for the random effect panel regression, the panel Poisson random effect model and the panel Negative Binomial model.

…………Eqn 1

…………Eqn 2

where is the patent of the ith manufacturing firm at year t, is the logarithmic of the research and development of the ith manufacturing firm at time t and represents the set of control variables comprising scientific and logarithmic of capital.

From the above, we note that Equation 1 measures the current effect of research and development on patents whiles Equation 2 incorporates lagged effect of research and development which extends to the fifth previous year, corresponding to the lagged specification of Hall, Griliches and Hausman(1986).

**Results**

**Testing Assumptions**

*Individual Effects*

In this stage, we test the null of the absence of individual effects in random panel estimation. The test reveals that there exist individual random effects in model without the lag values of research and development ( = 15587.85, p = 0.000) and the model with the lag values of research and development ( = 1762.66, p = 0.000).

Moreover, the Poisson random panel effects also show that significant individual effects on both the equation without the lags of research and development ( = 57035, p = 0.000) and the equation including the lags of research and development ( = 21828, p = 0.000). As expected, the Negative binomial random panel regression shows similar individual effects: on the equation without the previous values of research and development ( = 5530, p = 0.000) and on the equation involving the previous values of research and development ( = 1701, p = 0.000). In all cases, the panel data estimations are better suited for the data than pooled regression analysis.

*Collinearity*

In this stage, we examine collinearity among the variables of the model using techniques that shown how related these variables are in modelling. Table 1 below shows the correlation metric of the estimated coefficients. We note that aside correlations with the constant term which tends to be high with the variables, correlations between pairs of coefficients are mild; an indication that collinearity may not be a problem in the data.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Table 1**. Correlation metric of estimated coefficients | | | | |
|  | logrd | logcapital | scientific | \_cons |
| logrd | 1 |  |  |  |
| logcapital | -0.385 | 1 |  |  |
| scientific | -0.136 | 0.1805 | 1 |  |
| \_cons | 0.2681 | -0.8377 | -0.4705 | 1 |

Though the collinearity analysis for model without the lags of the variables (Mean VIF = 2.48), as expected, there is evidence of multicollinearity in the model with the lags of research and development (Mean VIF = 47.72).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Table 2**. Collinearity Results of Variables | | | | |
|  | VIF | SQRT VIF | Tolerance | R-Squared |
| patents | 1.6 | 1.26 | 0.6251 | 0.3749 |
| logrd | 3.66 | 1.91 | 0.273 | 0.727 |
| logcapital | 3.39 | 1.84 | 0.2953 | 0.7047 |
| scientific | 1.27 | 1.13 | 0.7849 | 0.2151 |
| Mean VIF | 2.48 |  |  |  |

*Auto-Correlation*

The study uses bias-corrected Born and Breitung (2016) Q(p) test shows evidence of autocorrelation in the model. The test is on null hypothesis of no serial correlation up to order p. The test statistics on lag of the residual (Q(p) = 9.58, p = 0.002), on the first order (LM(k) = 3.06, p = 0.002) and on the second order (LM(k)-stat = 2.91, p = 0.004). However, the residuals of the lagged model of research and development shown no evidence of autocorrelation: on lag of residual (Q(p)-stat = 0.64, p = 0.423), on first order (LM(k)-stat = 0.99, p = 0.321) and on the second order (LM(k)-stat = - 0.31, p = 0.757).

*Exogeneity*

In panel data specification, the Hausmann test is used to examine exogeneity. In essence, it is a Hausmann test of specification that tend to differentiate between whether there is difference in coefficients are systematic (alternative hypothesis) or not (null hypothesis). The test rejects the null hypothesis ( = 54.11, p = 0.000) which confirms endogeneity. However, the test is not appropriate for the model with the lagged values of research and development because the fixed effect model specification has overall statistical insignificant. Additionally, the Hausmann-Wu procedure confirms that the research and development variable is endogenous in model with or without the lags of research and development (p = 0.000).

*Heteroskedasticity/Homoscedasticity*

In this stage, we examine the nature of the variance of the residuals. The null hypothesis is that the variance of the residuals is constant (homoscedasticity) against the alternative that the variance is not constant (heteroskedasticity). The null hypothesis is rejected for both the model without lags of research and development (F = 5.21, p = 0.0057) and model with lags (F = 3.14, p = 0.0440). Hence there is evidence of heteroskedasticity.

**Regression Estimation Results**

Next, we examine the regressions estimation results of random effect, panel Poisson random effect and panel negative binomial random effect. The random effect and panel Poisson random effects are clustered by firm to account for possible overdispersion (Cameron and Trivedi, 2013), autocorrelation and heteroskedasticity.

Table 5 below shows the estimation of equation 1 and equation 2 using three (3) different models: (1) the random effect panel regression, (2) the Poisson panel random effect model and the negative binomial panel random effect model. All model estimations show evidence of overall statistical significance. The output across models and equations tends to be consistent. There is a positive effect of current research and development on patents. Hence an increase in research and development increases the development of patents, all things being equal. For models estimated with the previous annual value of research and development, the positive significant effect is strongest on the previous second year which then declines in magnitude gradually after the previous second year. The results further show that capital and scientific institutions have positive effects on patents.

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| **Table 5**. Effect of Research and Development on Patent | | | | | | |
|  | Random Effect | | Poisson | | Negative Binomial | |
|  | (1) | (2) | (3) | (4) | (5) | (6) |
|  | 1.547\*\*\* | 2.491\*\*\* | 0.158\* | 0.248\*\*\* | 0.152\*\* | 0.323\*\*\* |
|  | (0.472) | (0.484) | (0.0846) | (0.0513) | (0.0707) | (0.0227) |
|  | 1.094\* |  | 0.00341 |  | 0.0584 |  |
|  | (0.565) |  | (0.0983) |  | (0.0842) |  |
|  | 2.090\*\*\* |  | 0.222\*\*\* |  | 0.190\*\* |  |
|  | (0.527) |  | (0.0748) |  | (0.0806) |  |
|  | 1.853\*\*\* |  | 0.162\*\* |  | 0.181\*\*\* |  |
|  | (0.528) |  | (0.0713) |  | (0.0679) |  |
|  | 1.513\*\*\* |  | 0.0879 |  | 0.105\* |  |
|  | (0.564) |  | (0.0617) |  | (0.0619) |  |
|  | 1.248\*\* |  | -0.0145 |  | -0.0190 |  |
|  | (0.584) |  | (0.0835) |  | (0.0598) |  |
| Log Capital | 9.907\*\*\* | 16.43\*\*\* | 0.241\*\*\* | 0.510\*\*\* | 0.143\*\*\* | 0.223\*\*\* |
|  | (1.436) | (1.899) | (0.0527) | (0.0460) | (0.0364) | (0.0239) |
| scientific | 12.92\*\*\* | 21.45\*\*\* | 0.103 | 0.490\*\*\* | 0.0154 | 0.219\*\*\* |
|  | (4.766) | (4.571) | (0.0982) | (0.0954) | (0.0892) | (0.0695) |
| Constant | -22.61\*\*\* | -41.90\*\*\* | 0.382\*\* | -0.206 | 0.915\*\*\* | 0.601\*\*\* |
|  | (4.986) | (5.831) | (0.159) | (0.137) | (0.151) | (0.0986) |
| Observations | 1,926 | 5,136 | 1,926 | 5,136 | 1,926 | 5,136 |
| No of Firms | 642 | 642 | 642 | 642 | 642 | 642 |
| Wald chi2 | 103.1 | 106 | 6589 | 5740 | 1519 | 1113 |
| Prob > chi2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| sigma\_u | 49.42 | 51.89 |  |  |  |  |
| sigma\_e | 10.14 | 13.15 |  |  |  |  |
| rho | 0.960 | 0.940 |  |  |  |  |
| Log-likelihood | |  | -5244 | -14920 | -5073 | -13515 |
| LR test of alpha=0 | |  | 21828 | 57035 | 1701 | 5530 |
| Prob (LR test) | |  | 0.000 | 0.000 | 0.000 | 0.000 |
| alpha |  |  | 0.903 | 1.014 |  |  |
| **Notes.** Robust standard errors in parentheses for Random Effect regression and Poisson panel (random effect) regressions: Models (1), (2), (3) and (4). Standard errors in maximum likelihood for Negative Binomial (random effect) regressions: Models (5) and (6). \*\*\* p<0.01, \*\* p<0.05, \* p<0.1 | | | | | | |

Table 6 provides the result of examining the effect of research and development on patents for both Poisson and Negative Binomial where estimation is the population-averaged model for nonnegative count dependent variable with overdispersion. Generally, we observe that there is a positive effect of current research and development on patents. Additionally, the previous second year impact of research and development on patents is positive and statistically significant.

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| **Table 6**. Effect of Research and Development on Patent (Population Mean Estimation) | | | | |
|  | Poisson | | Negative Binomial | |
|  | (1) | (2) | (3) | (4) |
|  | 0.103 | 0.335\*\*\* | 0.387\*\*\* | 0.469\*\*\* |
|  | (0.0704) | (0.0384) | (0.107) | (0.0336) |
|  | -0.0205 |  | -0.0510 |  |
|  | (0.0854) |  | (0.119) |  |
|  | 0.192\*\*\* |  | 0.268\*\* |  |
|  | (0.0600) |  | (0.109) |  |
|  | 0.149\*\* |  | 0.0678 |  |
|  | (0.0666) |  | (0.102) |  |
|  | 0.0818 |  | 0.0984 |  |
|  | (0.0525) |  | (0.0820) |  |
|  | 0.0206 |  | -0.0138 |  |
|  | (0.0690) |  | (0.0749) |  |
| logcapital | 0.259\*\*\* | 0.428\*\*\* | 0.143\*\*\* | 0.353\*\*\* |
|  | (0.0479) | (0.0340) | (0.0372) | (0.0332) |
| scientific | 0.323\*\* | 0.497\*\*\* | -0.0114 | 0.294\*\*\* |
|  | (0.157) | (0.130) | (0.0902) | (0.0859) |
| Constant | 0.537\*\*\* | 0.108 | 0.613\*\*\* | 0.151 |
|  | (0.182) | (0.151) | (0.129) | (0.127) |
| Observations | 1,926 | 5,136 | 1,926 | 5,136 |
| Number of Firms | 642 | 642 | 642 | 642 |
| Wald chi2 | 768.3 | 988.3 | 2046 | 1839 |
| Prob > chi2 | 0.000 | 0.000 | 0.000 | 0.000 |
| chi2\_dev | 30303 | 91548 | 2050 | 5587 |
| chi2\_dis | 15.73 | 17.82 | 1.064 | 1.088 |
| **Notes**. Robust standard errors in parentheses. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1 | | | | |

**Discussion**

The paper examined the impact of current and previous research and development on patents of 643 manufacturing firm from the year 1972 to 1979. The results reveal that there exists positive statistically significant current and previous years’ impact of research and development on patents. The paper also demonstrated the use of panel count models such as the Poisson and Negative Binomial random effects specifications on establishing the relationship between patents, and research and development. As expected, scientific-oriented firms show positive attitude towards patents development. Future research could explore the possibility of reverse causality effect from patent development on future research and development. Due to the limited number of control variables examined, there could be the possibility that other important conditions that determine patents successful applications could not be captured. Future research could also explore some of these variables in estimation.

**Conclusion**

Patents can provide source of competitive advantage to manufacturing firms. Using patent information on 643 manufacturing firms, this paper has established that both current and previous years’ research and development are positively related to successful patents applications. Moreover, the effect was high for the previous two (2) years of research and development.

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