International Congress on Environmental Modelling and Software

2nd International Congress on Environmental Modelling and Software - Osnabrück, Germany - June 2004

Jul 1st, 12:00 AM

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Abstract: This paper introduces a simple new measure of innovation, the patent success ratio (PSR), namely the ratio of successful patent applications to total patent applications. It has been argued in the extensive literature on innovation and technology policy that patents can serve as an accurate proxy for innovative activity. This paper suggests that PSR is a more accurate measure of how innovative activity changes over time than are transformations of total patent applications and successful patent applications separately. A sensitivity analysis is conducted to assess the usefulness of the new PSR measure of innovation using annual US data for the period 1915-2001.

Key Words: Innovation, patent activity, patent success ratio, successful patent applications, total patent applications.

1. Introduction

This paper introduces a simple new measure of innovation, the patent success ratio (PSR), namely the ratio of successful patent applications to total patent applications. Gallini (2002) provided a survey of the literature of patents as instruments of innovation. McAleer, Chan and Marinova (2002) were the first to explore the time series properties of patent activity for the leading inventive countries by modelling the volatility inherent in monthly US patent shares. The concept of inventiveness primarily involves information content. A key issue is whether the PSR conveys more meaningful information, and hence yields greater explanatory power of a key economic fundamental, by combining the two patent activity variables, namely successful patent applications and total patent applications, than either conveys individually.

It is argued in this paper that the information content in PSR regarding innovation is greater than in its two separate components. In order to assess the usefulness of PSR, we compare it with transformations of the other two patent activity variables in their respective abilities to serve as leading indicators of the real GDP growth rate. If a variable is to serve as an accurate proxy for innovation in the US economy, it should be the case that the proxy will be correlated with fundamental economic variables such as real GDP growth. A sensitivity analysis is performed to examine how the new measure compares with two other indicators of innovation, namely successful patent applications and total patent applications, that are commonly used in the literature.

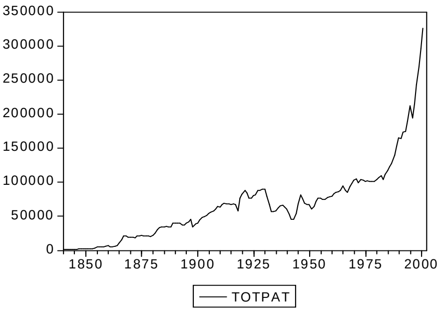
Data on patent applications and patents granted (equivalently, successful patent applications) have been collected by the United States Patent and Trademark Office (USPTO) for an extended period, with some series dating back to 1790. The USPTO decomposes patent activity into domestic and foreign companies and individuals, among other categories. As such disaggregated patent data are available, we will examine transformations of total patent applications and successful patent applications separately, before combining them into PSR in the empirical analysis.

The plan of the paper is as follows. Section 2 discusses the sources of data and their time series properties. Section 3 presents a sensitivity analysis using annual US data for the period 1915-2001 to compare the usefulness of the new PSR measure of innovation relative to transformations of total patent applications and successful patent applications separately. Section 4 concludes the paper.

2. Data

In this paper, the simple new measure of innovation to be defined and examined is the patent success ratio (PSR), namely the ratio of successful patent applications to total patent applications. The new measure is analysed using annual US data from the USPTO for the period 1915-2001, and a sensitivity analysis is conducted to assess the usefulness of the new PSR measure of innovation. USPTO data are available for total patent applications, as well as successful patents (namely, granted patents) to domestic companies and individuals, from 1840 (for further details regarding the data sources, definitions and availability, see http://www.gov/web/offices/ac/ido/oeip/taf/h_counts.htm).

Figure 1
Total Patent Applications
1840-2001



Figures 1-4 present the time series plots of total patent applications, successful patent applications (or patents granted) and PSR for the period 1840-2001, and the growth in real US GDP for 1915-2001. Data for the growth in real GDP start in 1915 because the CPI (consumer price index) data used to deflate nominal US GDP starts in 1915.

Figures A.1 and A.2 present the time series plots of the growth rates for total patent applications and successful patent applications. These two series are clearly stationary, or I(0) processes. The volatility in the growth rate in total patent applications has generally decreased over time, whereas the volatility in the growth rate in successful patent applications fell appreciably until the end of World War II and then increased for the next three decades.

Figure 2
Successful Patent Applications
1840 - 2001

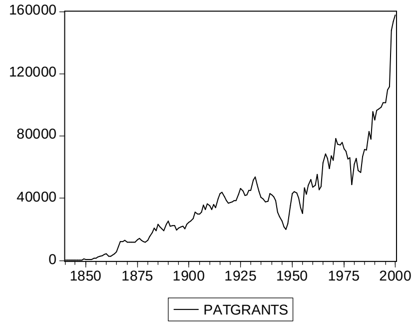


Figure 3
Patent Success Ratio
1840 - 2001

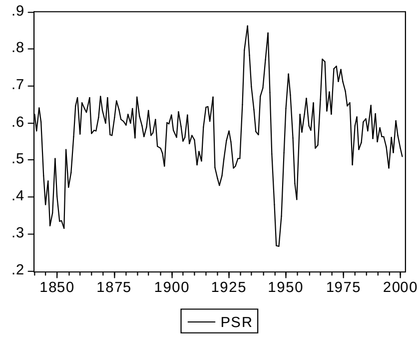


Table 1 reports the corresponding summary statistics for total US patent applications, successful patent applications, PSR and the growth rate in real GDP. It is clear that the real GDP growth rate has the highest standard deviation (SD) relative to its mean, whereas PSR has the lowest SD relative to its mean. As can readily be seen, the two patent activity variables have an increasing trend overall, with a significant reduction during 1930-50, which coincides with the depression and the immediate post-war period. There is also a noticeable fall in successful patent applications after 1975 following the first oil price shock. The PSR exhibits significantly greater volatility, ranging between a low of around 0.25 to a high of around 0.85. Growth in real US GDP does not appear to have a clear trend, but the volatility has declined consistently over time.

extracted from transformations of either total patent applications or successful patent applications as proxies for innovative activity. This issue is examined in greater detail in the following section.

Table 1: Summary Statistics of Patent Activity Variables, 1840-2001

Statistics	Total Patent Applications	Successful Patent Applications	Patent Success Ratio (PSR)	Real GDP Growth Rate (1915-2001)
Mean	66,967	38,976	0.57	3.58
SD	56,863	32,227	0.10	8.01
Skewness	1.74	1.41	-0.44	-1.36
Kurtosis	4.86	5.72	3.97	6.18

Figure A.1
Total Patent Applications
Growth Rate
1840 - 2001

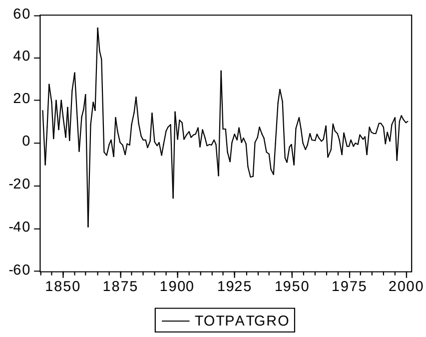


Figure 4
Growth in Real U.S. GDP
1915 - 2001

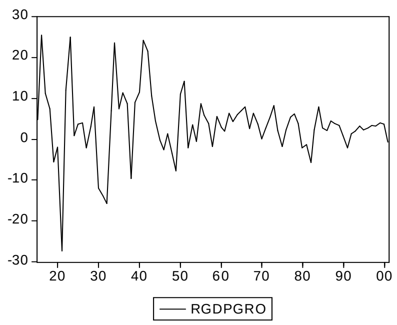
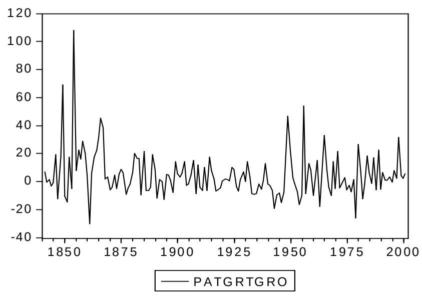


Figure A.2
Successful Patent Applications
Growth Rate
1840-2001



Figures 1-4 indicate that PSR exhibits quite different behaviour from the trending behaviour seen in both total patent applications and successful patent applications, as well as from the real GDP growth rate. In addition, the simple correlation coefficients were calculated for the real GDP growth rate, PSR and the growth rates in total patent applications and successful patent applications, and are presented in Table A.1. The simple correlation coefficients indicate little correlation between the real GDP growth rate and the growth in the other patent activity variables, and a positive, but moderate, correlation with PSR. These results suggest that PSR may yield different information than might traditionally be

3. Empirical Results

A simple check of the effectiveness of PSR as a measure of innovation is to examine the correlation between PSR and economic growth. One way of analysing any correlation is to perform Granger (1969) (non-) causality tests. Calculating such Granger causality tests can be informative for at least two reasons: (1) as will be shown below, these tests give an indication of the relationship between PSR and the growth rate in real US GDP; (2) these tests allow an examination of the relative benefits of PSR as a proxy for innovation compared with other patent activity variables, namely transformations of total patent applications and successful patent applications separately. Thus, if it is found that PSR Granger-causes economic growth, while the two other proxies for innovation do not, this is informative as an assessment of the relative value of PSR as an innovation proxy and predictor of real economic growth.

Table 2 presents the results of some Granger-causality tests to examine the level of association between the new innovation measure and growth in real GDP. A brief discussion of the Granger-causality test is given, for example, in Slottje (2004). Granger (1969) proposed a simple and effective test of whether x "causes" y, such that y is said to be "Granger-caused" by x if lagged values of x are significant in the prediction of y. Thus, if the addition of lagged values of x improves the prediction of y, x is said to "Granger-cause" y. These tests are, in effect, a measure of association and should not be construed as a measure of (logical) causation. In order to implement the Granger-causality test, the estimating equations take the following form:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \dots \alpha_k y_{t-k} + \beta_1 x_{t-1} + \dots + \beta_k x_{t-k} + \varepsilon_t \quad (1a)$$

$$x_t = \lambda_0 + \lambda_1 x_{t-1} + \dots \lambda_k x_{t-k} + \delta_1 y_{t-1} + \dots + \delta_k y_{t-k} + \mu_t \quad (1b)$$

The test of Granger-causation between x and y is an F-test of the joint hypothesis that

$$\beta_1 = \beta_2 = \dots = \beta_k = 0 \quad (2a)$$

$$\delta_1 = \delta_2 = \dots = \delta_k = 0 \quad (2b)$$

The null hypothesis in (2a) is that x does *not* Granger-cause y, while the null in (2b) is that y does *not* Granger-cause x. If the null is rejected in (2a) but is not rejected in (2b), the Granger-causation is said to be unidirectional from x to y.

In order to implement this approach, we perform Granger-causality tests on PSR, total patent applications and successful patent applications, with respect to the rate of growth in real US GDP. However, the regression equations will not be balanced in all cases. An examination of the time series properties of PSR and the rate of growth in real GDP indicate that both are integrated of order zero, I(0), such that they are stationary in levels. Total patent applications and successful patent applications are integrated of order 1, I(1), so that regressions of these variables against the growth rate in real US GDP would not be balanced.[1] Therefore, a direct comparison of the relative performance of the three innovation proxies against the growth rate in real GDP is not available. Nevertheless, the growth rates of total patent applications and successful patent applications are stationary, so transformations of these two patent activity variables can be tested for Granger-causality with respect to the rate of growth in real GDP.

Table 2. Granger Causality: PSR and RGDP

Lags: 2

Null Hypothesis	Obs	F-Statistic	Probability
PSR does not Granger-cause RGDPGRO	85	3.154	0.048
RGDPGRO does not Granger-cause PSR		0.804	0.451

Table 2 shows that a Granger-causality test of PSR against the growth rate in real US GDP indicates a Granger-causal relationship in the expected direction at the 5% level of significance. As the results in Table 2 indicate that the new innovation variable, PSR, Granger-causes the rate of growth in real GDP, but not the reverse, this suggests that PSR is a useful new indicator of innovative activity.

Given the presence of unit roots in the patent activity variables discussed above, it is not possible to provide a direct comparison with the total patent applications or successful patent applications. However, when the other

[1] See Dickey and Fuller (1979) for further details. The augmented Dickey-Fuller (ADF) test statistics for the four variables, with probability values in parentheses, are -5.11 (0) for PSR, -6.65 (0) for the growth in real US GDP, 1.92 (0.923) for successful patent applications, and 6.6 (1.0) for total patent applications, respectively.

innovation proxies are log-differenced, we achieve stationary series for both successful patent applications and total patent applications.[2] The Granger-causality tests for the rates of growth in total patent applications and in successful patent applications are given in Table 3 and 4. These results are not informative about the Granger-causality with the rate of growth in real GDP, but are reported for completeness.

Table 3. Granger Causality: Total Patent Growth and RGDP

Lags: 2

Null Hypothesis	Obs	F-Statistic	Probability
TOTPATGRO does not Granger-cause RGDPGRO	85	6.097	0.003
RGDPGRO does not Granger-cause TOTPATGRO		2.921	0.060

As can be seen in Table 3, we cannot reject the hypothesis that either variable Granger-causes the other at the 10% level of significance. Table 4 suggests that neither growth rate is significant at any conventional levels in explaining the other. However, since these two tables refer to the growth rates for the two innovation proxies, a direct comparison of these growth rates with PSR is not strictly possible. Overall, it is clear that PSR yields useful information and significant predictive power in its correlation with the growth rate in real GDP for the USA over the period 1915-2001.

Table 4. Granger Causality: Successful Patent Growth and RGDP

Lags: 2

Null Hypothesis	Obs	F-Statistic	Probability
RGDPGRO does not Granger-cause GRANTGRO	85	1.259	0.290
GRANTGRO does not Granger-cause RGDPGRO		0.054	0.948

[2] The augmented Dickey-Fuller statistics, with probability values in parentheses, are -8.83 (0) and -5.73 (0), respectively.

Table A.1. Simple Correlation Coefficients

Variable	RGDPGRO	PSR	TOTPATGR	PATGRTGR
RGDPGRO	1.00	0.34	-0.23	-0.11
PSR	0.34	1.00	-0.45	0.13
TOTPATGR	-0.23	-0.45	1.00	-0.06
PATGRTGR	-0.11	0.13	-0.06	1.00

4. Concluding Remarks

This paper introduced a simple new measure of innovation, the patent success ratio (PSR), namely the ratio of successful patent applications to total patent applications. The simple new measure is useful as it gauges the relative efficiency of patent applications over time. There have been clear upward trends in both patent applications and successful patent applications since 1840. However, as shown in the paper, the ratio of successful patent applications to total patent applications has fluctuated significantly over time. A sensitivity analysis was conducted using annual US data for the period 1915-2001 to examine the usefulness of the new PSR measure of innovation compared with transformations of total patent applications and successful patent applications separately. The growth in the simple new measure of innovation had a stronger association with the growth in real GDP than did growth in total patent applications or the growth in successful patent applications. Future research will show how the measure is correlated with other macroeconomic fundamentals in determining the relationship between innovative activity and economic growth.

5. Acknowledgements

The authors are grateful to Jim Hirabayashi of the USPTO for useful information regarding some data sources. The first author wishes to acknowledge the financial support of the Australian Research Council.

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