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Abstract

We investigate the effect of quality of patents on the market value of firms represented by the Tobin's q. We consider the number of objections as well as the number of citations. We construct the database of patent stock, citation-weighted patent stock and objection-weighted patent stock. Our analysis is pioneering work involving Japanese data, as we were unable to find any pre-existing Japanese data that considered both truncation problems and quality of the patent. Our study departs from Hall, Jaffe and Trajtenberg (2000) because of the application of objections as well as the consideration of the quality of patent citations.

JEL classification number: O31,O32,O34

Key word: Patent, Citation, q, Market value, Innovation

1 Introduction

We empirically studied the market value of firms and patents by analyzing whether the patents of Japanese firms where the quality of the patents is considered, contribution to the market value of the firms, represented as the Tobin's q.

Since Schumpeter's study (Schumpeter (1942)), it has been recognized that innovation plays an important role for the competition and growth of the firm. This concern with innovation has been increasing since the 1990s, with development of the new growth theory (Grossman and Helpman (1991)) and firm strategy theory (Porter (1990)). Research and development (R & D) is increasingly invested for innovation. Such innovation is protected by the patent system because imitations discourage innovations and are eventually reflected in the decrease of the competitive advantage of both industries and nations. There are several factors, including patents, that investors consider when making investment decisions. A valuable patent increases the market value of the given firm.

Several studies have appeared since Griliches (1981) to analyze the relationship between Tobin's q representing the market value of firms and intangible assets such as patents. Haneda and Odagiri (1997) is a notable previous paper that used the approach of Griliches (1981), applied to Japan. These studies demonstrate the problem of the construction of the data of patents. The construction method used by Haneda and Odagiri (1997) is the summation of past patent applications. However not every patent application is granted. It is considered that patent grants are reflections of innovations (Hall, Jaffe and Trajtenberg (2000)). Therefore, we must employ patent grants for construction of the present patent stock. Moreover, Griliches (1981) and Haneda and Odagiri (1997) assumed that the quality of different patents is identical. However, it is obvious that the quality of patents will differ. Hall, Jaffe and Trajtenberg (2000) constructed patent data by considering the quality. At the same time, they empirically found that the quality of patents significantly contributed to the market value of the firms represented as the Tobin's q.

Our study is based on Hall, Jaffe and Trajtenberg (2000). Our analysis is pioneering work involving Japanese data, as we were unable to find any pre-existing Japanese data that considered both truncation problems and quality of the patent. Hall, Jaffe and Trajtenberg (2000), on the other hand, measured the quality of patents by patent citations. Lanjouw and Schnkerman (2001) and (2004) pointed out that valuable patents attracted many lawsuits from rival firms. In Japan, applications of "in opposition to the granting of a patent", an "offer of information" or "objection for appeal for invalidation" to the Japan Patent Office instead of litigation in court are popular. We call these "objections" in this paper. Hence we employ a number of objections to measure the quality of patents. Therefore, our study departs from Hall, Jaffe and Trajtenberg (2000) because of the application of objections as well as the consideration of the quality of patent citations.

Our presentation is organized as follows. A description of the model is presented in Section 2. Data and the estimation methods are presented in Section 3. Empirical results are presented and discussed in Section 4. The conclusion is presented in Section 5.

2 Model

Many previous studies since Griliches (1981) have tested the effectiveness of intangible assets such as patents. Tobin's q is represented as the ratio of the market value of the firm to its capital stock. We consider the following equation for market values of firms and their assets:

$$V(t) = \alpha(A(t) + \beta R(t)), \tag{1}$$

where the $V(t)$ denotes the market value of the firm; $A(t)$ is the real capital stock; $R(t)$ is the intangible asset; and α and β are parameters. The market value of a firm is represented by a linear combination of its real assets and its intangible assets. An increase in the intangible assets is expected to result in an increase of the market value of the firm. We obtain the following equation using the traditional Tobin's q:

$$q(t) = \frac{V(t)}{A(t)} = \alpha(1 + \beta\frac{R(t)}{A(t)}), \tag{2}$$

where $q(t)$ denotes the Tobin's q. We consider that a patent is an intangible asset. Hence, R & D stock, patent stock, citation stock and objection stock are incorporated into our model. On the other hand, if we employ R & D for the intangible assets, we must control for the quality of the R & D[1]. Hence, patent stock, citation stock and objection stock are incorporated to control for the quality of R & D. We obtain the following estimation equation:

$$q(t) = \alpha(\beta_0 + \beta_1\frac{R\&D(t)}{A(t)} + \beta_2\frac{PS(t)}{R\&D(t)} + \beta_3\frac{CIS(t)}{PS(t)} + \beta_4\frac{OBJ(t)}{PS(t)}), \tag{3}$$

where $R\&D(t)$ denotes the R & D stock; $PS(t)$ is the patent stock; $CIS(t)$ is the citation stock; and $OBJ(t)$ is the objection stock. The above equation is identical to the model of Hall, Jaffe and Trajtenberg (2000), except for the last term that is the objection stock. We consider the objection stock as well as the citation stock, which is different from Hall, Jaffe and Trajtenberg (2000). Equation (3) is estimated using nonlinear least squares. Dummy variables for the different industries are included in our model.

[1] See Hall, Jaffe and Trajtenberg (2000).

3 Data

We present the details of the data of patents in this section. The construction method for data on patents in the early studies (Griliches (1981), Cokburn and Griliches (1988) and Haneda and Odagiri (1998)) involved the summation of the past patent applications[2]. This method assumes that the past patent applications are associated with innovations. However not every patent application is granted. There is considerable validity in the claim that patent grants reflect innovations (Hall, Jaffe and Trajtenberg (2000)). Therefore, we employ the patent grants for the construction of the present patent stock[3]. Hall, Jaffe and Trajtenberg (2000) assumed that the quality of a patent depended on the citation of the patent. Hence, the citation-weighted patent stock is constructed[4].

We construct the database for patent stock, citation-weighted patent stock and objection-weighted patent stock for the 101 Japanese companies. It is difficult to construct the data of patent stock because there are no databases containing data such as day of patent applications and grants, number of citations and objection in Japan. The SBI corporation developed a database of patents called "Stravision" that contains data such as the day of patent applications and grants, number of citations and objections in June 2005. We employ the data of patent grants of 101 Japanese large corporations from January 1985 to August 2006 and construct three variables of patent data that are patent stock, citation-weighted patent stock and objection-weighted patent stock using Stravision. We can now also use the patent data from the Institute of Intellectual Property (IIP). Our data are essentially identical to the IIP Data Base (Goto and Motohashi(2007)).

The method of correction of truncation bias of patent stock is same as that used in Hall, Jaffe and Trajtenberg (2000). The inverse weight is calculated using an application grant lag distribution constructed from the cohort of patent applications from the latter half of the 1980s[5]. The values of the inverse weights are shown in Table A1 in the Appendix.

The method of correction of truncation bias for both the citation and objection is the same as in Hall, Jaffe and Trajtenberg (2000). However, we only employ the data on both citations and objections that are cumulative numbers[6]. Therefore, we cannot specify the time of either the citation or the objection. Hence, we employ the model of citation probability to estimate both the citation lag distribution and objection lag distribution[7] .

[2] $PS(t) = (1-\delta)PS(t-1) + A(t)$ where δ is the obsolescence rate and $A(t)$ is the amount of patents applied for at time t.

[3] $PS(t) = (1-\delta)PS(t-1) + G(t, t+i)$, where $G(t, t+i)$ is the amount of patents applied for at time t and granted at time $t+i$.

[4] $CIS(t) = (1-\delta)CIS(t-1) + CI(t, t+i)$, where $CI(t, t+i)$ is the amount of citations received at time $t+i$ to patents applied for at time t.

[5] We could not use the application grant lag distribution of the 1990s because it took too long to be granted from the date of the application.

[6] We could only obtain data on the cumulative numbers of both citations and objections.

[7] $ln(CA_k(s,t)/P_k(s)) = \phi_k + \psi_k(1/L)$. where $CA_k(s,t)$ is the number of cumulative citations at time t to patent applied for at time s in the k-th industry or comulative objections at time t to patent applied for at time s in the k-th industry; $P_k(s)$ is the number of

The applied year effects for five years are considered. The estimation results are in Tables A2 and A3 in the Appendix. We assume that the periods of the births of both the citations and objections are 24 years.

The market value of the firm is calculated by multiplying the market price of a share of common stock by the number of shares outstanding, and adding the book value of the debt and subtracting the liquid assets. The replacement value of an asset is the sum of the tangible assets and land. The tangible assets are calculated by using the perpetual inventory method whereby the initial value is that given in 1970. The land value is also calculated by the perpetual inventory method, in which the incremental value of the land is applied to the new investment of the land and initial value of the land is taken to be its value in 1970. Tobin's q is calculated by dividing the market value of the firm by the replacement value of the firm. The R & D stock is calculated by the using perpetual inventory method where the initial value is the value in 1970.

The primary data source, except for patents, is NEEDS (Nihon Keizai Shinbunsha). Furthermore, Kabuka Souran (Toyo Keizai) is used for the share price, Shigaichi Kakaku Shisu (Nihon Fudosan Kenkyusyo) is used for land price and Japan Industrial Productivity Database (JIP DATA) from Research Institute of Economy, Trade and Industry (RIETI) is used for the depreciation rate.

4 Results

[Table 1]

We investigate the characteristics of our data that are used for the empirical analysis. The statistical results include the number of sample observations, the mean and the standard deviation, as shown in Table 1. The number of sample observations is about 1200. The mean value of the Tobin's q is 3.3. This value is apparently larger than that in Hall, Jaffe and Trajtenberg (2000) and Haneda and Odagiri (1997). On the other hand, our value is close to that in Miyagawa and Kim (2006). The sample period of our study is close to that in Miyagawa and Kim (2006). The value of our R & D stock-asset ratio is larger than that in Hall, Jaffe and Trajtenberg (2000) and Haneda and Odagiri (1997). Furthermore, the value of our R & D stock-asset ratio is also larger than that in Miyagawa and Kim (2006). However, the differences between ours and those in Miyagawa and Kim (2006) are not very large. Our citation-patent stock ratio is much larger than our objection-patent stock ratio. The latter ratio is 10%.

[Table 2]

The estimation results for equation (2) that the independent variable related to both R & D and patents as intangible stock are shown in Table 2. Estimation results are as follows. R & D, patent, citation and objection

patent applications in the k-th industry applied at time s; and L is the number of years to time t from time s.

are significantly positive in all results from column (1) to column (4). Hence, the increase of each variable results in an increase of the Tobin's q. Our results are the same as those in Hall, Jaffe and Trajtenberg (2000) and Haneda and Odagiri (1997). Objections are not included in the model of Hall, Jaffe and Trajtenberg (2000). Hall, Jaffe and Trajtenberg (2000) assert the importance of citations. However, we obtain estimation results that the objections are important as well as citations.

[Table 3]

Values of each elasticity of Tobin's q are shown in Table 2. Our R & D elasticity of the Tobin's q is 0.3. Our value is smaller than that in Hall, Jaffe and Trajtenberg (2000) and almost the same as that in Haneda and Odagiri (1997). Our patent elasticity of Tobin's q is 0.45, which is larger than our R & D elasticity. Furthermore, our patent elasticity is larger than that in Hall, Jaffe and Trajtenberg (2000) and Haneda and Odagiri (1997), except for that applicable to the drug industry. Our citation elasticity of Tobin's q is 0.46. Our value is much larger than that in Hall, Jaffe and Trajtenberg (2000). Our objection elasticity of Tobin's q is 0.39. The objection is not included in the estimation equation of Hall, Jaffe and Trajtenberg (2000). However, we obtain estimation results that the objections are important as well as citations. There are possibilities that all variables contribute to Tobin's q in this result. There is interdependence among R & D, patents, citations and objections. We construct a model that considers all these variables.

[Table 4]

The estimation results of the model that includes patents, citations and objections are shown in Table 4. The results are summarized as follows. R & D, patents, citations and objections are significantly positive in all results from column (5) to column (8), except for the patents in column (5). Hence, increases of each variable result in increases of Tobin's q. This result is the same as that for our results for the model in which there is only one independent variable for intangible stock. This means that our results are quite robust to different specifications of the model.

[Table 5]

Results of elasticities are in Table 5. The results are summarized as follows. The R & D elasticity of Tobin's q ranges from 0.3 to 0.5 and is larger than that for other variables. The patent elasticity is smallest for all variables. The citation elasticity and the objection elasticity are almost identical. Our R & D elasticity is smaller than that in Hall, Jaffe and Trajtenberg (2000) and our citation elasticity is larger than that in Hall, Jaffe and Trajtenberg (2000). Hall, Jaffe and Trajtenberg (2000) asserted that citations are valuable to evaluate patents precisely. Our results indicate that the importance of citations is the same as that found in Hall, Jaffe and Trajtenberg (2000). Moreover, objections are also important to evaluate the quality of patents. There are no previous studies that assert the importance of objections. However, we note the importance of objections as well as citations. In our study, there are some cases where the objection elasticity is larger than that for citations.

5 Concluding Remarks

We investigate the effect of quality of patents on the market value of firms represented by the Tobin's q. We consider the number of objections as well as the number of citations. We construct the database of patent stock, citation-weighted patent stock and objection-weighted patent stock for 101 Japanese companies. The method of correction of truncation bias of patent stock is same as used in Hall, Jaffe and Trajtenberg (2000).

R & D, patents, citations and objections are significantly positive in all results. Hence, increases of each variable result in increases of Tobin's q. Our results are almost the same as in Hall, Jaffe and Trajtenberg (2000) and Haneda and Odagiri (1997). Hall, Jaffe and Trajtenberg (2000) indicated the importance of citations. Objections were not included in the equation of Hall, Jaffe and Trajtenberg (2000). However, we obtain estimation results that show the importance of objections as well as citations. Objections were not included in the estimation equation of Hall, Jaffe and Trajtenberg (2000). There are some cases in our study where the objection elasticity is larger than that for citations. We found that patents play an important role as the intangible stock, as indicated in Griliches (1981) and Hall, Jaffe and Trajtenberg (2000).

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Table 1: Summary Statistics of Sample Firms Observations

Variable	*Observations*	*Mean*	*Stdard Deviation*
$Tobin's\ q$	1220	3.3764	3.238463
$R\&D\ stock/assets$	1223	.6065604	.5957658
$Patent\ stock/assets$	1223	.0106344	.0108428
$Patent\ citation/assets$	1223	.0176593	.0211502
$Patent\ objection/assets$	1223	.0008957	.0011227
$Patent\ stock/R\&D\ stock$	1223	.0388228	.0545268
$Patent\ citations/Patent\ stock$	1223	1.563437	.568762
$Patent\ objection/Patent\ stock$	1223	.095353	.0986438

Table 2: Regression Results for Log of Tobin's q (t-ratio in parentheses)

	(1)	*(2)*	*(3)*	*(4)*
$Constant$	1.35995	1.315587	1.331746	1.390776
	(15.44)	(15.29)	(15.72)	(15.86)
$R\&D\ stock/assets$	.3428058			
	(5.40)			
$Patent\ stock/R\&D\ stock$		28.36897		
		(5.75)		
$Patent\ citations/Patent\ stock$			17.57841	
			(6.74)	
$Patent\ objection/Patent\ stock$				296.5526
				(6.66)
$D(Drugs = 1)$	.760485	1.09179	1.103006	1.051266
	(8.22)	(13.39)	(13.68)	(13.00)
$D(Chemicals = 1)$	-.020779	-.0134524	-.0403566	-.1158894
	(-0.29)	(-0.19)	(-0.58)	(-1.61)
$D(Electrical = 1)$	.7446032	.5638873	.5681708	.6157942
	(10.23)	(7.09)	(7.47)	(8.18)
$D(Precision = 1)$	.784301	.6081671	.5460016	.5874686
	(8.61)	(6.45)	(5.82)	(6.26)
R^2	0.3312	0.3427	0.3581	0.3493

Table 3: Estimated Elasticities

	(1)	*(2)*	*(3)*	*(4)*
$R\&D\ stock/assets$	.33273			
$Patent\ stock/R\&D\ stock$		.45128		
$Patent\ citations/Patent\ stock$			.46155	
$Patent\ objection/Patent\ stock$				.3902

Table 4: Regression Results for Log of Tobin's q (t-ratio in parentheses)

	(1)	*(2)*	*(3)*	*(4)*
$Constant$	.880272	1.013314	.970442	.8647335
	(7.72)	(10.82)	(8.47)	(7.22)
$R\&D\ stock/assets$	.5307884	.6737467	.5262191	.7090891
	(4.15)	(4.96)	(4.73)	(4.36)
$Patent\ stock/R\&D\ stock$	1.113547	1.799562		1.808871
	(1.42)	(2.34)		(2.03)
$Patent\ citations/Patent\ stock$	.3363164		.1915289	.1822742
	(3.14)		(2.02)	(1.74)
$Patent\ objection/Patent\ stock$		4.109405	3.160266	3.804618
		(4.26)	(3.56)	(3.57)
$D(Drugs = 1)$	.8490048	.6405979	.7117616	.7051297
	(8.96)	(6.79)	(7.26)	(7.18)
$D(Chemicals = 1)$	-.0524837	-.1991908	-.2141618	-.187061
	(-0.72)	(-2.48)	(-2.75)	(-2.35)
$D(Electrical = 1)$	.7314851	.6267386	.659978	.6453234
	(10.17)	(8.48)	(8.97)	(8.75)
$D(Precicson = 1)$	.7066502	.6623713	.6381808	.646384
	(7.70)	(7.18)	(6.92)	(7.00)
R^2	0.3498	0.3614	0.3611	0.36

Table 5: Estimated Elasticities

	(5)	*(6)*	*(7)*	*(8)*
$R\&D\ stock/assets$	.679	.958	.721	.859
$Patent\ stock/R\&D\ stock$	.075	.134		.115
$Patent\ citations/Patent\ stock$	.893		.548	.465
$Patent\ objection/Patent\ stock$		.755	.512	.574

Appendix

Table A1 Weighting Factorsfors for Patent Applications

Year	*Inverse Weight*	*Year*	*Inverse Weight*
1977	1.50	1996	1.08
1978	1.23	1997	1.26
1979	1.09	1998	1.81
1980	1.03	1999	3.00
1981	1.01	2000	5.43
1982-1993	1.00	2001	12.20
1994	1.01	2002	32.98
1995	1.02		

Table A2: Estimation of Citation Probability

variables	*coeffient*	*S. E.*
$Industry\, Field\, Effects$		
$Drugs$	0.030	0.133
$Chemicals$	0.252	0.094
$Precision$	0.717	0.133
$Transportation$	0.243	0.106
$Electrical (= base)$	-0.613	0.180
$Drugs \times \frac{1}{L}$	-5.495	1.225
$Chemicals \times \frac{1}{L}$	-1.163	0.489
$Precision \times \frac{1}{L}$	-6.927	1.225
$Transportation \times \frac{1}{L}$	-2.373	0.700
$Electrical (= base) \times \frac{1}{L}$	-5.583	0.493
$Applied\, Year\, Effects$		
$2000 - 1996$	0.891	0.124
$1995 - 1991$	1.389	0.150
$1990 - 1986$	1.343	0.162
$1985 - 1981$	0.970	0.170
R^2	0.956	

Table A3: Estimation of Objection Probability

variables	*coefficient*	*S. E.*
$Industry\ Field\ Effects$		
$Chemicals$	1.189	0.136
$Transportation$	-0.074	0.157
$Electrical(= base)$	-4.036	0.119
$Chemicals\ \times\ \frac{1}{L}$	-0.875	0.607
$Transportation\ \times\ \frac{1}{L}$	-1.955	1.003
$Electrical(= base)\ \times\ \frac{1}{L}$	-0.537	0.202
$Applied\ Year\ Effects$		
$1995 - 1991$	0.398	0.136
$1990 - 1986$	0.815	0.142
$1985 - 1981$	1.279	0.145
R^2	0.860	