Paper to be presented at the DRUID Academy conference in Rebild, Aalborg, Denmark on January 21-23, 2015

Producing Quality Inventions: Evidence from Swiss Firms

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Abstract

1. STATE OF THE ART
There is a growing literature that validates patent quality metrics against real phenomena. In the context of the pharmaceutical industry, Wagner & Wakeman (2014) employ patent quality metrics, and find â??further evidence of the relationship between a broad range of patent-based measures and the outcomes of the patenting process (pg. 28).â?• Using semi-structured interviews, Kapoor & Karvonen (2013) confront practitioners with typical bibliometric patent quality indicators with the aim of validating them and assessing their relevance. In the most recent work using European survey data, Toma (2014) shows how a composite quality index explains about 10% of the reported value of patents. In a similar vein, using patent auction data, Fischer & Leidinger (2014) show that both the technical relevance and the commercial protection are positively and significantly related to the value of a patent.

More practically, patent quality metrics have since become mainstream, making their way into OECD cross-country comparisons of technological performance. Furthermore, patent indicators serve an important role for management in assessing competitors and identifying potential technological threats, and take-over targets; numerous patent indices from private providers have made their way into the market.

In short, both the literature and real money being spent provide ample support for the notion that patent quality metrics capture something â??realâ?• about the value of the innovative output of a firm.

2. CONTRIBUTION
The contribution of this paper is to change patent quality from an explanatory variable to a dependent variable. the hitherto approach of using patent counts as a proxy for technical change is a conceptually inadequate measure of innovation because a patent is foremost a legal right, not an invention per se. the literature assumes that innovations can be produced by adding the typical inputs (e.g. capital & labor), it logically follows that patent quality would issue from the same set of determinant factors. By using a firmâ??s patent quality rather than its patent count as a measure of innovation, the idea is to capture more of the relative innovative capacity of the firm, and thereby test common notions about the determinants of innovation.

3. THEORY

The theory is fairly straight forward in that it is a test of the cumulative findings of the innovation literature. A firmâ??s patent quality should in theory be determined by essential the same factors of other innovation models, to wit:

1. Physical capital, as measured by R&D expenditures;
2. Human capital, as measured by the share of educated labor;
3. Demand, as measured by managements expectations;
4. Economies of scale in intellectual property, as measured by the number of employees or turnover;
5. Technical potential of a field, as measured by management's assessment;
6. Market structure + competition, as measured by a state of oligopoly or perfect competition;
7. Appropriability, as measured by the perceived level of legal/patent protection patents provide.

4. METHODS AND DATA

At its core, the paper employs two basic econometric methods, the first is simple OLS. We first test our data where we understand the basic outcomes based on the previous literature. Because the marginal effects of the innovation production function may not be constant, we also deploy quantile regression.

The data comprise two main types: 1. firm characteristics, like R&D expenditures; 2. firm patents. The former is drawn from the KOF Innovation Survey 1990-2013, the Swiss analog to the European Innovation Survey. Each firm in the survey was matched with its worldwide portfolio of patents using PATSTAT and Espacenet. The basic unit of observation is a 3 year cross-section where firms are asked about their activities in tâ??1,â??2,â??3, and the patents are matched in the subsequent 3 year period, t+1,+2,+3. From their ca. 595,000 patent documents, a series of 12 basic quality/value indicators were derived largely following Squicciarini et al. (2013). Using these 12 indicators, a single patent quality index was formed using the principal component with the highest eigenvalue as in Lanjouw & Schankerman (2004). Next, the patent quality index was aggregated at the median patent by three-year period and firm, thus forming the dependent variable of interest.

5. (PRELIMINARY) RESULTS

Whereas the standard innovation model explains patent counts well, we find the quality of invention does not rely on the same set of predictors. This principal finding suggests that patents may be a proxy for the legal strategy, which surrounds innovative activities, but not necessarily a metric for innovation or invention itself.

Jelcodes:O32,O32

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(Conference draft, do not cite, or share)

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January 18, 2015

Contents

1 Introduction

The practice of using patent application counts as a proxy for innovation has been widespread in the academic literature and become commonplace in international innovation indices, such as the WIPO's Global Innovation Index. In the face of large numbers of patents, the question of patent quality is one that increasingly

*I'd like to thank the Swiss Federal Institute of Intellectual Property (IGE) for its generous financial support, and Martin Wörter, my PhD supervisor, for his helpful tutelage. The author's statements do not necessarily reflect the position of the Swiss government or IGE; his errors and omissions are his own.

occupies academics, policy-makers, managers, who are all interested in knowing the intrinsic technical, legal, and economic quality of patents. This comes at the same time that there is a large debate in policy circles about "raising the bar" of patent quality as a bulwark against a surge of patents of dubious utility. In short, it has become patent that not all patents are based on useful or novel inventions, and might represent more a shift in the international IP framework and concomitant legal strategies. With more than 88 million patent publications, sifting the wheat from the chaff in a quantitative way promises both utility and insight.

The notion of patent quality is one that encompasses various aspects, and depends largely on the context of the discussion. In legal and governmental circles patent quality pertains to the legal basis of novelty and inventiveness, and juridical boundaries and clarity of the invention's description. In the economic literature, it is more or less synonymous with the technical and economic value of the patent. Within business circles it pertains to the legal scope, enforceability, and commercial viability of the invention. The notion of quality innate to the empirical strategic in this paper however mostly relies on the commercial value and technical quality of the invention.

2 Contribution

The contribution of this paper is to change patent quality from an explanatory variable of patent value to a dependent variable measuring innovative output. The hitherto approach of using patent counts as a proxy for technical change is a conceptually incomplete way to measure of technical innovation because a patent is foremost a legal right, not an invention *per se*. Because the innovation literature essentially assumes that innovations can be "produced" using economic or organizational inputs, it logically follows that patent quality would issue from the same set of determinant factors. By using a firm's patent quality rather than its patent count as a measure of innovation, the idea in this paper is to better capture of the relative innovative capacity of the firm, and thereby test common notions about the determinants of innovation against the understood attributes of patented inventions. In addition to furnishing a unique measure of firm innovation, the paper furnishes some insight into how patent quality metric might best be constructed.

2.1 Academic Literature

It has long been known in the academic literature that patent counts are correlated with innovation. Early works such as Scherer (1965*b*) or Scherer (1965*a*) use patent counts as a proxy for R&D and inventive output. And while the specialist patent literature had already empirically demonstrated the quality differences amongst patents using bibliometric attributes in the early 1980s, the economic literature of that time was primarily concerned with technological change as proxied by the quantity of patent output. Early writers were aware that simple patent counts were not entirely sufficient to capture the innovative prowess of a firm, but patent quality in the earlier work, such as Griliches (1980), was assumed away, presumably for practical computational considerations. It was Trajtenberg (1990) that largely brought patent indicators into the mainstream innovation economic literature. Since the incorporation of forward citations into the (biblio|econo)metrician's arsenal, numerous other value and quality traits have been uncovered and investigated; these are explored in more detail in Section 5.1. After a gestation period, Lanjouw & Schankerman (2004) pioneered a composite metric of patent quality based on a number of theretofore identified bibliometric attributes; the authors then validated their composite metric as a measure of value/quality using stock market data.

Beyond this, there is a growing literature that validates patent quality metrics against real phenomena. In the context of the pharmaceutical industry, Wagner & Wakeman (2014) employ patent quality metrics, and find "further evidence of the relationship between a broad range of patent-based measures and the outcomes of the patenting process (pg. 28)." Using semi-structured interviews, Kapoor & Karvonen (2013) confront practitioners with typical bibliometric patent quality indicators with the aim of validating them and assessing their relevance. In the most recent work using European survey data, Thoma (2014) shows how a composite quality index explains about 10% of the reported value of patents. In a similar vein, using patent auction data, Fischer & Leidinger (2014) show that both the aspects of technical relevance and commercial protection are positively and significantly related to the value of a patent. Continuing in this path, this paper tries to validate patent quality metrics as a plausible measure of firm innovative activity.

2.2 Non-Academic Uses

Beyond the academic literature, patent quality metrics have gone mainstream and are now integral to both the R&D process, competitor and market analysis. Patent indicators now serve an important role in management's assessment of competitors, enhancing its ability to identify potential technological threats and take-over targets. Along with the democratization of patent data, numerous private providers have sprung up.

In Europe, one of the major providers is Patent Sight. Patent Sight's Patent Asset Index comprises a company's patent *portfolio size*, the *market coverage* as measured by the GDP of jurisdictions where a patent is active, and *technology relevance* as measured by forward citations normed by industry, year, and jurisdiction Ernst & Omland (2011). While not particularly focused on inventive quality, the asset index does approximate the legal and commercial heft of a firm's portfolio. Similar to Patent Sight's index, the University of St. Gallen and BWG AG describe a valuation method in Swiss patent application CH705018A2; somewhat distinct in their approach is that technical relevance is defined as a percentile rank of citations in the empirical density function of a target technical field, rather than a raw forward citation count.

Ocean Tomo, a major North American player in patent consulting and valuation, boasts the "Ocean Tomo Ratings" system, which provides "meaningful business intelligence." The exact formulation of the system and the metrics used are opaque. Somewhat ironically, even the three business method patents[1], which supposedly protect the methodology, are quite vague about the specifics of the implementation. Presumably, the index relies on many of the aspects identified in the academic literature cited in the patents. The firm even offers an equity index based on a patent value or quality that purports to beat the S&P500 by 430 basis points annually. Thomson Reuters also offers some rudimentary tools as part of their patent information offerings. In a similar vein, the European Patent Office offers IPSscore. In addition to these, there are numerous other players in the field with their own unique methodologies; they all essentially rely on the same set of bibliometric traits. Beyond practical commercial applications, patent quality metrics have made inroads into OECD cross-country comparisons of technological performance.

In short, both the academic literature and real money being spent on patent intelligence indicate that there are good reasons to believe that patent quality metrics capture something "real" about the innovative output of patenting firms, if only imperfectly.

3 Theory

The theoretical relations tested in this paper largely build on the collective findings in the innovation literature. Cohen (2010) provides a comprehensive exploration of the various factors germane to firm innovation, which is omitted here. The aim in this paper is less to adjudicate between any of the theoretical minutiae of the innovation literature, and more to take the less controversial common elements of innovation models to form a plausible benchmark model. The theory underlying the empirics of this paper is thus fairly straight forward in that it is a simple test of the cumulative findings of the innovation literature using a different measure of innovation, namely patent quality. A firm's patent quality should in theory be determined by essentially the same factors found in a litany of other innovation models, to wit:

1. R&D expenditures are correlated with innovative output, and thus should be correlated with patent quality.
2. Exporters that face both transportation and sunk beachhead costs should be more productive, and are likely to have a have higher quality innovations that command higher markups (cf. Melitz (2003)).
3. Educated labor has been found to boost innovative output, and should increase patent quality.
4. Demand incentivizes a firm to pursue profits, and innovation is proximate to that goal, patent quality is thus likely to be correlated.

[1] U.S. patents 6556992, 7657476, 7716226

5. Whether firm size leads to greater innovation has been subject to debate, in the realm of patented technologies that can leverage global protection and distribution channels, one would expect these economies of scale to bolster the returns to high quality invention.
6. Technical potential or opportunity not only draws in R&D expenditures, innovations in fecund fields ought be of higher quality.
7. Market structure & competition are a bit ambiguous in the literature in the sense the monopoly confers profits to fuel R&D, but likewise undermines the firm's incentive to obsolete its own products.
8. Appropriability allows firms to profit from their innovations, higher levels of appropriability should thus lead to higher quality inventions.

Table 1: Specification of the Explanatory Variables

Variable	Description	E{Sign}	Mean (s.d.)
expectDemand	Management's demand outlook for its main markets	+	3.3 (0.86)
ln[firmSize]	Logged number of employees	+	5.337 (1.377)
ln[RnD]	Logged R&D expenditures	+	13.17 (3.499)
techPotential	Technological potential available to be exploited by firms active in the domain	+	3.3 (0.98)
grossMargin	Value-added as % of turnover	+	0.57 (0.366)
oligopoly	5 or fewer main competitors	+/-	0.29 (0.45)
shareHiEduc	Share of employees with tertiary degrees	+	0.24 (0.18)
exportShare	Share of sales to export markets	+	0.59 (0.59)
appropriability	Appropriability of innovation through legal rights and other mechanisms, such as lead time	+	2.95 (0.86)

4 Data and Methods

The paper essentially relies on a series of statistical techniques, first to correctly identify patent quality from a patent data, and second ascertain whether patent quality issues from the same underlying innovative process as do other common metrics of innovation.

4.1 Description of the Data

The data comprise two main types: 1. firm characteristics, like R&D expenditures; 2. firm patents. The firm data are drawn from the triennial Swiss Economic Institute (KOF), Innovation Survey 1990-2013, which is the Swiss analog to the Community Innovation Survey. The surveyed firms are drawn as random stratified sample from the Federal Statistical Office's firm census; firms in the survey have least five employees in manufacturing, construction, and services. These are surveyed by post using a detailed questionnaire (available from www.kof.ethz.ch) as to their characteristics and innovation activities. The response rate is typically a healthy 30-40%, whereby the surveyed firms cover about 33% of employment of the sampled population. The first two cross-sections only cover manufacturing. The final unbalanced dynamic panel comprises about 815 patenting firms over 8 time periods.

Each firm in the survey data was manually matched with its worldwide portfolio of patents using PATSTAT 2014a and Espacenet, yielding about 595,000 matched patent documents, and about 89,000 patent families; for each patent document, a series of 13 basic quality/value indicators were computed largely following Squicciarini et al. (2013). The firms in final dataset represent about 61% of the patent families generated by Switzerland-based entities during the same period.

Given these two primary data sources, the basic unit of observation throughout thus becomes a three-year cross-section of firm activities and characteristics in $t_{-1,-2,-3}$, and the firms' patents and quality are observed in the subsequent three-year period, $t_{+1,+2,+3}$. This lagged approach eliminates most, but not all, of the potential endogeneity issues associated with contemporaneous estimation, which will now be briefly addressed.

4.2 Statistical model

Since the primary goal here is to ascertain whether quality inventions can "be produced", this paper deploys several approaches to deal with a possibly incomplete firm-level model specification without using firm-level fixed effects. Perhaps the most common way to address omitted variable bias would be to use firm-fixed effects or first differences approach. Given the fact that the panel is very unbalanced, and that many firms are observed only in one triennial period, incorporating firm fixed effects would bias the sample as the larger and more established firms have longer time-series. Furthermore, given that many of the firm-level variables exhibit little variance over time, many, if not most, of the firm-level effects are captured by their traits. For this reason, we go out of our way to avoid the fixed-effects model by deploying robust, multivariate, joint estimation techniques, and quantile estimation techniques.

Nevertheless, given the rudimentary econometric framework employed, we refrain from making any causal statements. Rather, the results of this paper ought better for the moment be interpreted as partial correlations with theoretically appropriate explanatory variables, rather than absolute causal statements, or a refutation of a particular theory.

5 Patent Quality

In this section, we shall explore a series of empirical and theoretical reasons why patent quality and value can be measured using bibliometric measures. Then, initial evidence is provided why quality has been identified.

5.1 Manifestations of Patent Quality from the Literature

The literature surrounding patents is now replete with subtle correlations between a patent's bibliometric traits, and its value or underlying value. These range from simple, to complex requiring occasionally nuanced calculations. The 13 used in this paper represent the primary ones, but are by no means exhaustive. These are briefly explained below. Squicciarini et al. (2013) provides a much more thorough investigation of their statistical properties.

Claims: Number of claims in the patent document, a measure of strategic and legal value of a patent.

Adverse citations: This is like a backward citation measure, but it looks specifically at the fraction of backward citations (Xs, Ys) that are deleterious to novelty or inventiveness, a measure of legal robustness. Thompson (2014) shows how adverse citations are relevant for grant decisions, and can be used as a better measure of a patent population's legal and technical quality.

Forward citations: Number of forward citations are a measure of technical relevance. These appear as raw counts, or are occasionally normed by creating a window (typically 5 years). There are other norming techniques such as percentile ranking, industry ranking. This paper norms the counts by age and logs them.

Family size: Number of members in the docDB family; family sizes a measure of widespread commercial viability.

PCT status: Patent family has used the patent cooperation treaty (procedure) and has a WIPO application member. It is a measure of revealed patenting costs.

NPL count: number of citations to non-patent literature, a measure of technical relevance. Deng et al. (1999) finds this to be a statistically significant predictor of market value of listed firms.

Patent scope: is the unique number of IPC4 classes a patent has. It captures the applicability of the measure to various technical fields.

Grant count: number of granted family members, a measure of legal robustness.

Number of inventors: a measure of sunk research costs; presumably inventions issuing from large (expensive) teams are more valuable.

Active life: Sum of all active periods for a patent family's members, a measure of revealed value. Here it is normalized by the number of family members.

Generality: A measure of general commercial application of a patent, it refers to the concentration of a forward citations received by the from a given class of patents, normalized by the age of the patent (to avoid citation time attrition). Defined on the interval [0-1], patents with little generality are limited to a narrow field of application.

Grant lag: A measure revealed value, logged interval between first priority date and first grant within a patent family, normalized by average time to grant by cohort and application authority. Presumably, applicants with high quality patents want to swiftly guide them through the system.

Oppositions: High value or legally broad patents are often attacked *in utero*. This measure counts the number of legal oppositions launched against members of a patent family.

5.2 Decomposing Patent Quality

A key insight of Lanjouw & Schankerman (2004) was that using factor analysis of multiple indicators reduces the overall variance in the measurement of the underlying patent quality. The basic premise behind the analysis is that patent quality can better be measured by using a composite metric that eliminates much of the noise inherent to any one dimension. Table 2 reveals the raw relation between these measures.

Table 2: Correlation between Patent Quality Indicators

	PCT	Family size	Claims	NPL	Scope	Adverse cites	Grants	Oppositions	Inventors	Active life	FW cites	Generality	Grant lag
PCT	1												
Family size	0.38	1											
Claims	0.19	0.16	1										
NPL	0	0.01	0	1									
Patent scope	0.1	0.39	0.17	0	1								
Adverse cites	-0.02	-0.13	-0.04	0	-0.1	1							
Grants	0.1	0.33	0.12	0.01	0.36	0.03	1						
Oppositions	0.42	0.21	0.21	0	0.16	-0.07	-0.02	1					
Inventors	0.19	0.43	0.04	0	0.16	-0.06	0.15	0.2	1				
Active life	-0.44	-0.42	-0.17	0	-0.19	0.01	0.03	-0.25	-0.19	1			
FW cites	0.16	0.31	0.17	0	0.53	-0.05	0.15	0.18	0.15	-0.17	1		
Generality	0.22	0.38	0.15	0	0.59	-0.09	0.02	0	0.2	-0.28	0.4	1	
Grant lag	0.2	0.16	0.05	0	0.12	-0.02	-0.02	0.38	0.23	-0.08	0.08	0.14	1

Not all the correlations are noteworthy, but a few stand out as needing a comment. Upon closer inspection, the negative relation between the PCT status and the total active life of the patent has to do with the fact that there a many "stub" applications that get filed via the PCT procedure, but never make into the national phase (or last only a short time therein). So while a patent filed via the PCT, pursued through all national grant phases, might be a good indication of expense, the simplicity of the procedure also lends itself to mass filings. It looks like there is some tradeoff between wide-coverage as evidenced by the family size and the duration of the coverage as captured by the negative correlation of -0.44. While non-patent literature (NPL) seems to have lost much of its salience, the remaining faint correlation between grants reinforces the notion that these patents are possibly closer to the cutting edge of science.

Using these 13 sub-indicators, a single patent quality index was formed using the principal component with the highest Eigenvalue. To avoid excess lossage in the PCA step, missing values for some of the patent document indicators were imputed using Gary King's Amelia II for R. Table 3 reveals the loadings of the various sub-indices.

There is no guarantee that "patent quality" can be identified using principal components analysis because it presumes that such a common factor underlies the various manifestations of quality identified in the literature. Table 3 displays the factor loadings for the first four components identified using scaled PCA.

Table 3: PCA Decomposition vs. Theory

	'Patent Quality'	PC2	PC3	PC4	E{Sign}
PCT	0.24	-0.34	0.26	-0.25	+
Family size	0.44	0.06	0.27	0.10	+
Claims	0.17	-0.20	-0.09	-0.49	+
NPL cites	0.00	0.01	0.02	-0.04	+
Patent scope	0.40	0.10	-0.40	-0.05	+
Adverse cites	-0.10	-0.01	0.02	-0.50	-
Grants	0.37	0.32	0.21	0.22	+
Oppositions	0.24	0.38	0.24	-0.46	+
Number of inventors	0.20	-0.52	0.22	-0.08	+
Active life	0.28	-0.01	0.41	0.27	+
FW cites	0.33	-0.05	-0.42	-0.10	+
Generality	0.35	0.01	-0.44	0.16	+
Grant lag	0.08	-0.55	-0.07	0.24	-
Only Eigenvectors with an Eigenvalue > 1 shown.					

While the signs of the Eigenvectors are theoretically arbitrary, their patterns are not. The last column of Table 3 displays the pattern of signs we would expect to see were there something akin to "quality". With the exception of the grant lag, the first principal component seems to fit the theoretical bill for something akin to patent quality/value. The other components do not have any obvious interpretation to the author. Figure 1 lends credence to the idea that the first component says something important about the nature of the patent.

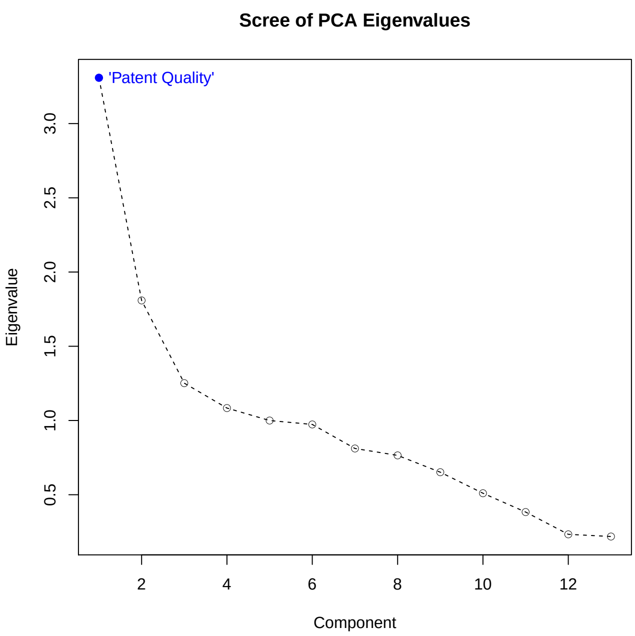

Figure 1: The scree plot for the 13 principal components reveals that one component describes a decent portion of the variance between patents.

Figure 2 shows the distribution of patent portfolio quality using a few common measures; with many odd distributions, it paints a vivid picture as to why no single metric is a robust proxy for patent quality. Through the normalization procedure inherent to the principal components analysis, the resultant distribution is more amenable to regression analysis. But beyond the pure mechanics of OLS there is good theoretical justification for using the "quality index" over the individual covariates in that principal components should be tossing out many of the aspects correlated with the innovation model covariates for reasons beyond patent quality. For example, the firms that report a high level of appropriability may use a lengthy procedure as a strategy.

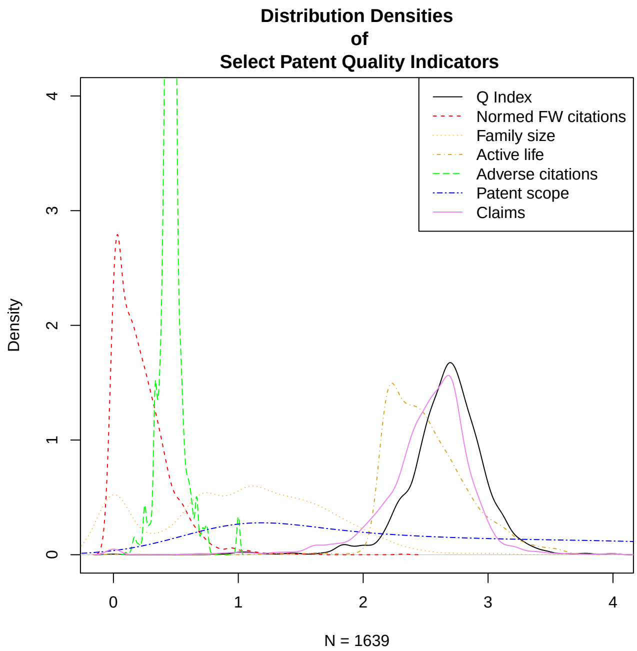

Figure 2: The distribution of patent portfolios formed on each of the indicators has a distinct distribution. The quality index (in black) "normalizes" these.

Next, the patent quality index was aggregated at the mean patent by three-year period and firm. The solid black distribution in Figure 2 shows the distribution of the variable of interest, patent quality. Having now presumably identified something akin to patent quality, we now incorporate it into our innovation model in the next section.

6 Results

6.1 Baseline Innovation Model

To demonstrate the validity (or at least the plausibility) of the basic underlying innovation model, we tested it against two benchmarks. The first is the innovation model based where the measure of firm innovation is proxied by patent counts. Using the same model, we then tested it using the sales share of innovative products. Table 4 presents the results. Recall that he explanatory variables are lagged by a period.

Table 4: Benchmark Innovation

	ln[Patent Quantity]		Share of innovative sales	
	Coefficient	s.e.	Coefficient	s.e.
(Intercept)	-285.91**	104.52	5.83	6.707
ln[RnD]	2.71*	1.27	0.926***	0.214
expectDemand	7.59*	3.28	2.033**	0.732
ln[firmSize]	30.4***	9.14	-2.269***	0.586
techPotential	5.37	3.55	2.176**	0.698
grossMargin	17.79	24.8	-4.118	3.755
$grossMargin^2$	-2.26	3.11	0.291	0.455
oligopoly	-11.32'	5.86	-1.706	1.417
shareHiEduc	74.4**	25.6	11.403**	4.392
exportShare	-6.11	7.61	10.814***	2.041
appropriability	9.18**	3.49	2.268**	0.73
ln[patentQuality]	-0.19	5.67	0.994	1.82
	R^2=0.24; p-value=0.000		R^2=0.12; p-value=0.000	

N=1611. Pooled OLS with robust errors clustered on firms; year fixed effects.

As one might expect, Table 4 reveals that higher R&D expenditures lead to both more patents and a higher sales share of innovative products; it is worth noting that at the margin, R&D seems to contribute more to patenting than final innovative sales figures. Perhaps a bit surprising is that management's expectations of future demand contributes more at the margin to patenting than final sales. One noteworthy incongruence is the fact that firm size correlates positively and significantly to patent output, but negatively and significantly to firm sales. The fact that large firms patent more is no surprise in that an invention, once discovered, can be reproduced at zero marginal cost, yields vast economies of scale; the fact that large international firms dominate the patent landscape is well known. This small firm innovative sales effect has been found in other KOF studies, but is likely to be more a numerical artifact than a statement about the relative innovative prowess between small and large firms—any given innovation simply does not move the needle much for firms with a lot of turnover.

Unsurprisingly, firms with a more educated workforce tend to be more innovative, but education would appear more pertinent to patent output than all types of innovative sales, as evidenced by a marginal coefficient that is about six times as high. Similarly, effective legal protection for innovations (be it designs, copyright, patents) would seem to be more closely tied to patenting behavior than innovative sales in general.

In general, the model has poor predictive power: the R^2 of the regression indicates that only 10-25% of the overall variance in innovate output is accounted for; that said, firms' patenting behavior is about twice as predictable as the final sales numbers for their innovative products. Using similar data, but a different framework, Arvanitis & Hollenstein (2006) obtains similar predictive power.

At this point our reader should be at least somewhat persuaded that the baseline model does a reasonable job of predicting innovation, so we now turn to our variable of interest – the patent quality index.

6.2 Predicting Patent Quality

This section looks at patent quality by testing the various measures of patent quality on our baseline innovation model. Table 5 presents the results of this investigation.

6.2.1 Comparison of Indicators

Table 5: Common Patent Indicators Compared

	Q Index	FW Cites	famSize	Lifespan	Adverse cites	Scope	Claims
(Intercept)	2.359***	-0.025	0.283'	2.376***	0.470***	0.629	2.22***
	0.068	0.056	0.160	0.081	0.023	0.669	0.089
ln[RnD]	0.007'	0.001	0.001	0.003	-0.001	0.032	0.007*
	0.004	0.002	0.006	0.003	0.001	0.021	0.003
expectDemand	0.013	0.013'	0.035'	0.013	0.003	0.075	0.013
	0.010	0.007	0.020	0.010	0.003	0.097	0.010
ln[firmSize]	0.014'	0.008	0.030'	0.002	0.002	-0.002	0.023*
	0.008	0.005	0.017	0.008	0.003	0.067	0.009
techPotential	0.007	0.011'	0.012	0.007	-0.003	0.231**	-0.032
	0.009	0.006	0.019	0.009	0.003	0.081	0.0067
grossMargin	0.031	0.020	0.149	0.046	-0.016	1.119*	-0.033
	0.058	0.039	0.118	0.054	0.014	0.550	0.067
$grossMargin^2$	-0.006	-0.003	-0.008	-0.009	0.002	-0.131	0.001
	0.009	0.006	0.018	0.008	0.002	0.081	0.018
oligopoly	0.018	-0.027*	-0.022	0.028	0.000	-0.616***	0.054*
	0.019	0.012	0.035	0.019	0.006	0.153	0.022
shareHiEduc	0.101'	0.088*	0.004	0.008	0.013	0.538	0.008
	0.059	0.041	0.105	0.050	0.016	0.500	0.050
exportShare	0.007*	0.007	0.134*	0.061*	-0.007	0.354	0.049
	0.028	0.018	0.056	0.026	0.008	0.235	0.03
appropriability	0.003	0.022***	0.069***	-0.027*	-0.001	0.240**	0.004*
	0.003	0.006	0.019	0.011	0.003	0.087	0.011
ln[patentOutput]	0.000	0.0002**	0.0004**	0.000	0.000	0.000	0.000
	0.000	0.00	0.0001	0.00	0.00	0.00	0.00
R^2	0.05	0.05	0.06	0.02	0.013	0.06	0.06
Pooled OLS N=1611, year fixed effects. Robust errors clustered on firms below estimates.							

Firm size appears to be positively and significantly correlated with at least three quality measures. Whereas in addition to being theoretically ambiguous, competition, as measured by a state of oligopoly, is empirically ambiguous depending on which measure of patent quality is used based on the mixed and significant signs presented above. We also see that exporters tend to have inventions with broad and long-lived patent families. The positive and significant coefficients of the patent quantity and appropriability tell us that big patentee that rely on the patent system's legal framework tend to attract more attention in terms of citations, and have bigger families. But in terms of our main variable of interest, RnD, firm size, education, and exporter status seem to be the most relevant.

6.2.2 Multivariate Multiple Regression

Another approach to testing the patent quality metrics against the innovation model is to use multivariate multiple regression. Using the same specification as in Table 5, but using all 13 indicators, we develop a system of equations using each of the sub-components as an outcome variable, and test the outcome variables jointly on the innovation variables (**X**) against the null hypothesis of no effect.

$$FWcites_i = \beta\mathbf{X} + \epsilon \tag{1}$$
$$\vdots$$
$$claims_i = \beta\mathbf{X} + \epsilon \tag{2}$$

The advantage here is that multivariate tests are typically more powerful than their univariate brethren. Again, we deploy the cross-sectional single period lag to militate against certain types of endogeneity.

Table 6: MANOVA Patent Quality Model

	LN[PATENTQUALITY]	
Variable	p-value	p-value
ln[RnD]	0.06'	0.01**
expectDemand	0.87	0.21
ln[firmSize]	0.03*	0.01**
techPotential	0.85	0.88
grossMargin	0.57	0.15
grossMargin^2	0.41	0.33
oligopoly	0.76	0.11
shareHiEduc	0.96	0.00**
exportShare	0.22	0.00***
appropriability	0.00**	0.00***
ln[patentOutput]	0.99	0.02*
Year effects	0.00***	0.00***
Firm effects	0.00***	-
Pillai test statistic		

Table 6 reveals agreement with the estimation for the patent quality index, R&D, firm size, education, and exporter status seem to be the most relevant. The more powerful multivate test also picks up the appropriability statistically significant effect that we saw in the FW cites, family size, patent scope, and claims sub-indices in Table 5, but not in the patent quality index. Less salient are the education, patent activity, and target markets, and whose effects disappear when accounting for firm-level specificities.

6.2.3 Joint Estimation of Common Error

Another approach to avoid including firm-level fixed effects, but address possible inconsistent estimation of potentially omitted variables is to estimate the patent quality equation jointly with other outcome variables whereby any systematic errors ought be similar. The potential correlation in the error term across models should allow us to better identify the effects of the covariates in the patent quality equation. Table 7 presents the results of this approach.

Table 7: Seemingly Unrelated Regression

	ln[PatentQuality]		ln[patentOuput]		Share of inno sales	
(Intercept)	2.24***	(0.07)	-259.24***	(25.81)	25.61***	(6.38)
ln[RnD]	0.01**	(0.00)	2.42**	(0.86)	1.11***	(0.21)
expectDemand	0.00	(0.01)	4.91	(3.0)	1.75*	(0.72)
ln[firmSize]	0.01*	(0.01)	28.88*	(2.01)	-2.61***	(0.51)
techPotential	0.01	(0.01)	4.71	(2.66)	1.85**	(0.64)
grossMargin	0.05	(0.05)	17.97	(14.13)	-2.71	(3.41)
grossMargin^2	-0.01	(0.01)	-1.72	(1.81)	0.15	(0.44)
oligopoly	0.00	(0.02)	-9.92	(5.61)	-0.61	(1.35)
shareHiEduc	0.08	(0.05)	71.36	(14.46)	12.06***	(3.5)
exportShare	0.06*	(0.02)	-12.51*	(7.54)	10.96***	(1.8)
effLegalProtection	0.01	(0.01)	8.32	(2.98)	1.02	(0.72)
ln[PatentOutput]	0.00	(0.00)	-	-	0.02***	(0.01)
shareInnoTurnover	0.00	(0.00)	0.38	(0.1)	-	-
ln[PatentQuality]	-	-	5.4	(7.7)	-0.22	(1.86)
	R^2=0.071		R^2=0.22		R^2=0.15	
	N=1639. Year fixed effects. s.e.'s in parentheses.					

The results are not very different from the simple estimation. Table 7 reveals agreement with the estimation for the patent quality index, R&D, firm size, and exporter status seem to be the most relevant. The relevance of higher education disappears using this technique, but this could be because the 1993 cross-section's education variable had to be imputed using the other cross-sections, introducing noise. The correlations between residuals of the patent quantity and innovative turnover estimations are quite high at -.13. In contrast, patent quality seems to be its own beast as evidenced by the weak correlation between its model's residuals and quantity and innovative turnover, which are -0.0262 and 0.0050 respectively.

6.2.4 Non-parametric Investigation

Rather than test for significance in the frequentist sense, we also explore the variables in the non-parametric framework. This approach allows one to identify where a linear model may be inappropriate as well as investigate the conditional marginal effects of the variables under investigation. Figure 3 shows the results of this approach.

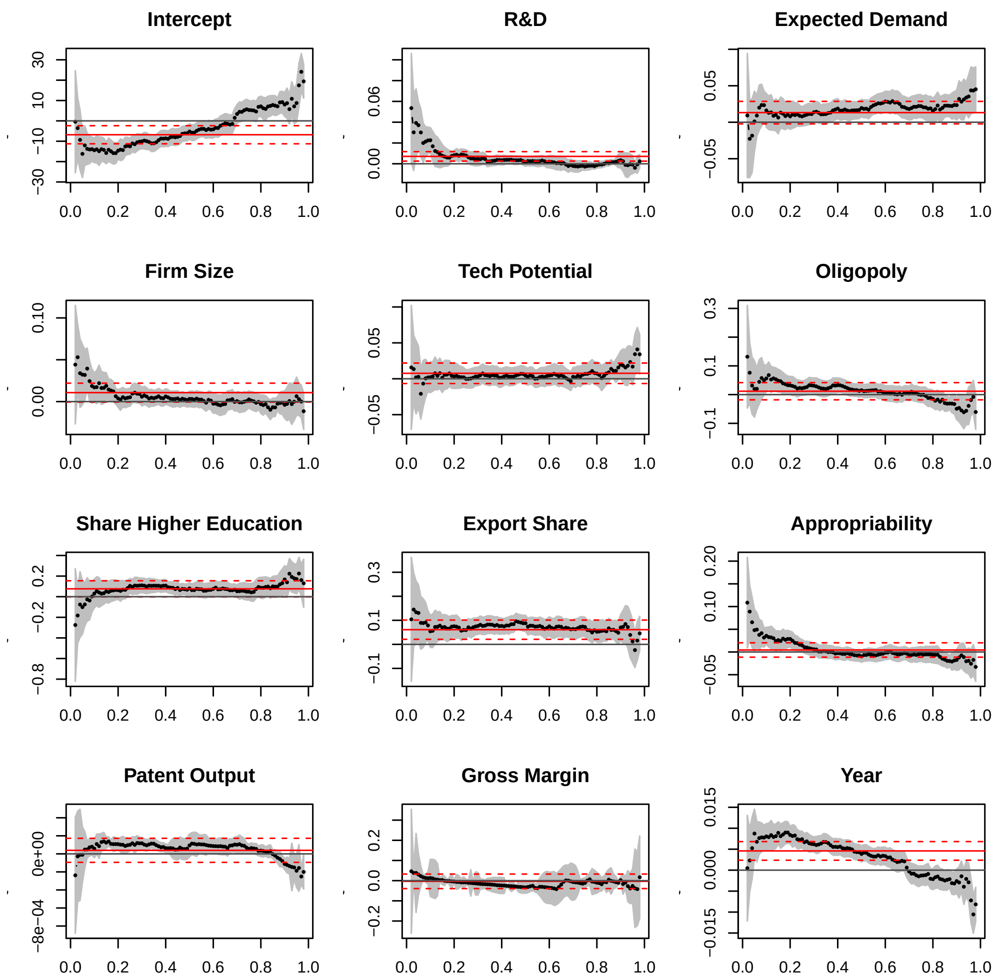

Figure 3: Tile plot quantile effects for the main variables of interest. 95% confidence intervals for the parameters dashed red; 95% CI for the quantile point estimates in the grey bands.

For the most part the errors of the quantile estimates intersect with the confidence intervals of the parameters; hence, we should be extremely cautious with over-interpretation. For firms with few R&D expenditures, the marginal effect of what R&D is spent would seem to have a larger effect at the lower quantiles. One banal interpretation is that smaller firms do not account for R&D as well as firms with bigger research budgets; that is to say expenditures get under-reported. Another interpretation would be that firms with smaller budgets spend the money more efficiently whereby only the highest quality projects get financed. In terms of the educated share of the labor force, which is noisily measured, missing qualified employees seems especially detrimental to patent quality, throughout the mid-range skilled and unskilled labor appear complementary, and at the high end of the range educated labor appears synergetic. At the extreme of big patenting firms, we can see quality declines, indicating some firms may be sacrificing quality for quantity, likely for strategic reasons seen in the legal patent literature. Both the downward sloping trends in both the oligopoly and appropriability panels of Figure 3 suggest that firms that are well insulated from competition produce inventions of lessor quality.

7 Conclusions

All the various techniques would seem to support the assertions that R&D, firm size, and export status are relevant for patent quality. The preponderance of the evidence supports the assertion that appropriability and education are as well. In contrast we cannot support the assertion that technological potential, market structure, demand, or margins foster patent quality. We also see evidence that patent quality seems to be a different type of innovative output in that the drivers are slightly different from those of patent output and innovative sales. While this does not invalidate common measures of innovation, it does raise questions about how different measures of innovation relate to common explanations.

In terms of future research, there are many practical questions about the best way to aggregate and transform the data for each of the indicators, which have not been systematically tested, but which would likely enhance the signal to noise ratio for the patent quality index. In terms of the innovation model, more efficient estimation techniques, including the addition of other covariates, could yield better measurements by disaggregating the patent portfolio and better accounting for patent-specific effects, and might eliminate remaining concerns of possible endogeneity.

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