Adaptive Multi-Method Valuation of Technological Intangible Assets in Asset-Light Firms

-- Exploratory Evidence from Public Technology Transactions and Listed-Company Cases

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Abstract

The role of technological intangible assets in the asset-light company is key to value creation, but limitations of the traditional valuation approaches exist at the various stages of commercialisation. This study presents an adaptive multi-method valuation framework by using both cost, income and market approaches in conjunction with historical-error-based weighting and leave-one-out validation. The three approaches have mean relative deviations of 25.14%, 10.01%, and 8.27%, respectively, based on 15 observations of the valuations. Results indicate that, valuation performance differs between assets and information conditions. The framework prevents leakage of information about the benchmark, offers the option of choosing a method when one method has a clear advantage, and offers a reproducible and interpretable tool for technology transfer, investment, financing and intangible-asset management.

Keywords

Asset-light firms, technological intangible assets, patent valuation, multi-method valuation, adaptive weighting.

1. Introduction

Technological intangible assets impact transaction pricing, financing, M&A, technology transfer and even asset management within the company in asset-light companies. They are not standardized tangible or financial assets and are highly dependent on legal safeguards, technological obsolescence, stages of commercialization, competition and the rules on the allocation of economic returns.

Valuation practice mainly relies on the cost, income, and market approaches. The cost approach is verifiable and does not take into account commercial premiums that go beyond R&D spend, the income approach is based on future benefits but is sensitive to revenue, contribution-rate, life and discount-rate assumptions, and the market approach is transaction based and relies on comparable and verifiable transactions. Their results may therefore differ significantly, and subjective choice of method or weighting decrease the reproducibility.

Patent-value research has evolved from single indicators to multidimensional and machine-learning frameworks[1,2,8,9,10], but much of it focuses on identifying high-value patents rather than estimating monetary value for transactions. This study asks whether historical valuation errors can generate interpretable adaptive weights and how target leakage can be avoided when samples are small and benchmark quality is heterogeneous.

Both learning weights and screening methods are based on historical or leave-one-out training errors: the adaptive valuation is a decision mechanism based on historical performance,

without taking into account the benchmark of the asset to be valued, when there is a clear information advantage of one method, screening is allowed. The study combines the three traditional methods and adds leave-one-out adaptive weighting and differentiates between actual transaction prices, contractual consideration, professional appraisals, and proposed transaction prices.

2. Literature Review and Research Hypotheses

2.1. The Multidimensional Evolution of Patent-Value Indicators

Initial patent value studies correlated patents' value to observable features, like forward citations, patent-family size, and opposition proceedings[7]. Further research added technological, market, legal, competitive and scientific dimensions[4,8,10], while Song et al. [9] added lifetime, strength, breadth and dispersion to encompass temporal and diffusion characteristics.

These indicators can be used to explain the technological quality, but are not directly transaction prices. Information about patents should therefore be used in conjunction with information regarding R&D inputs, attributable returns, the conditions of the transaction and the completeness of the rights for monetary valuation.

2.2. Applicability Boundaries of the Cost, Income, and Market Approaches

Hedonic Price models, pledge-loan analysis, renewal behaviour, and observed patent-auction prices were the bases for monetary-value research[1,2,3,5,6]. These methods extend the scope of measurement but suffer from the use of indirect proxies, limited transactions or selection bias.

The three traditional approaches are related to different information environments. The cost approach can be the most useful in situations where records of R&D are complete, but income is not yet established; the income approach is most appropriate for assets associated with identifiable products and cash flows; and the market approach is most effective when comparable transactions can be identified and are sufficiently similar. The selection of method should thus depend on the characteristics of the asset(s) and data availability.

2.3. From Fixed Weights to Historical-Performance Feedback

Fixed weights do not reflect changes in historical performance, while weights based on the asset's own benchmark will result in target leakage. A framework that can be implemented should only consider errors from the history or errors from the training sample, and should update the weights as new verifiable transactions are observed. The proposed mechanism thus is a decision layer over the three traditional approaches.

3. Data and Research Methods

3.1. Data Sources, Sample Boundaries, and Benchmark Hierarchy

The study uses four public data sources: 27 technology-transfer price observations from six universities, 2024 patent-licensing statistics from the China National Intellectual Property Administration, the transfer of 48 digital-technology intangible assets by GRG Banking, and two listed-company cases involving robotics and subsea-metering patents [D1–D10].

The 27 university observations form the initial comparable-price pool for the market approach. Twelve university assets with relatively complete valuation parameters, together with three listed-company asset-portfolio cases, form the 15-observation error-comparison sample. The remaining university observations are used only for price-range and comparable-case analysis.

Because disclosed prices differ in nature, the study adopts four benchmark levels: A, verified actual transaction or payment prices; B, contractual consideration; C, professional appraised values; and D, proposed or publicly disclosed negotiated prices. The term "reference benchmark value" is therefore used instead of "true value," and relative deviation is interpreted as deviation from the disclosed benchmark.

Table 1. Data Sources and Research Uses

Data source	Quantity / scope	Main research use	Nature of price / information
Six universities	27 single assets	Market-price range; comparable pool	Mostly proposed / disclosed negotiated prices
CNIPA licensing statistics	2024 statistics	Licensing-market reference	Registered contract statistics
GRG Banking announcement	48 digital assets	Income approach; portfolio case	Appraisal / transfer information
Jinfei Kaida announcement	4 robotics patents	Income approach; transaction case	Appraisal / consideration
Haimo appraisal report	32 subsea-metering patents	Cost approach; portfolio case	Professional appraised value

3.2. Three Base Valuation Approaches

(1) Cost approach. The cost approach is an estimate of replacement cost less technological, functional, and/or economic obsolescence. Replacement cost involves R&D labour and spending, application and registration expenses, materials and testing, and opportunity cost of capital:

$$V_C = C_R \times (1 - d)$$

where V_C is the cost-based value, C_R full replacement cost and d the comprehensive obsolescence rate. The R&D cycle, the remaining protection period, the technological iteration, and the substitute technologies should be used to determine the parameters before observing the reference benchmark of the asset. The method can offer an investment-based floor but it is not a measure of commercial value based on high expenditure.

(2) Income approach. Discounting the future income from the technological asset yields the income approach:

$$V_I = \Sigma[R_t / (1+r)^t], \; t = 1, 2, \ldots, n$$

where R_t is the expected income attributable, r is the discount rate, and n is the period of remaining economic benefits. Technology related income is estimated using revenue sharing. The ranges of exploration parameters are 3%–8% for the technology contribution rate and about 10%–12% for the discount rate, which should be determined ex ante based on the commercialization stage, the income attribution, the danger of substitution and the economic life.

(3) Market approach. The market approach begins with the similar transfer or licensing prices and then modifies for rights scope, technological maturity, timing of transaction, and form of transaction and for completeness of rights:

$$V_M = P_0 \times \prod k_j$$

where P_0 is a similar transaction price and k_j is an adjustment coefficient. The technique is largely based on the authenticity and comparability of cases. However, if similar transactions cannot be identified, the market approach is intended for use as a range reference and not as a point estimate.

3.3. Historical-Error-Driven Adaptive Weights

Let P_i be the reference benchmark of the historical case i and V_{ik} be the estimate obtained by method k $\in$ {C, I, M}. The relative deviation is:

$$e_{ik} = |V_{ik} - P_i| \ / \ P_i$$

The study employs leave-one-out estimation to avoid weights determined by the benchmark of case i that would otherwise influence the benchmark. Case i is omitted and the mean historical deviation of the method k is computed from the N−1 cases:

$$E_k^{(-i)} = (1/(N-1)) \ \Sigma_{h \neq i} \ e_{hk}$$

The weights are found by normalising the reciprocals of these errors in training:

$$w_k^{(-i)} = [1/(E_k^{(-i)}+\delta)] \ / \ \Sigma_j[1/(E_j^{(-i)}+\delta)]$$

where δ is a small, positive constant to avoid errors being dominated by very small errors. The sum of the estimates is $V_i^* = \Sigma_k \ w_k^{(-i)} V_{ik}$. In the case of a new asset, the same principle is used with all the known historical cases, that is, the unknown benchmark of the asset is never used in determining the weight.

3.4. Method Screening, Shrinkage, and Rolling Updates

Not all three of these methods have to be performed in each valuation. If one of the methods has a significantly lower historical error for comparable assets, and if the data quality is higher, the weight for that method can be increased or it may be considered independently. This prevents weak methods being used in the estimate, just for the sake of formality.

Historical errors can be rolled in (exponentially decayed) as new level A and B transactions become available, e.g., $E_{k,t} = \lambda E_{k,t-1} + (1-\lambda) e_{k,t-1}$, $0<\lambda<1$. The current sample size is too small to calculate an optimal λ, and rolling updating is still considered a future implementation mechanism, and not an empirical result.

4. Exploratory Empirical Results

4.1. Comparison of Deviations Across the Three Base Approaches

Across the 15 observations, mean relative deviations are 25.14% for the cost approach, 10.01% for the income approach, and 8.27% for the market approach; the corresponding ranges are 20.00%–33.50%, 5.46%–12.00%, and 6.00%–12.50%. Overall, with the current sample structure, cost-based estimates had the highest average deviations from reference benchmarks, and the market approach had the lowest average deviations, subject to the availability and comparability of market evidence.

Table 2. Relative Deviations of the Three Base Approaches for the 15 Observations (%)

#	Case	Type	Ref. value (RMB 10,000)	Cost	Inc.	Mkt.
1	Shangluo University — An Oxygen Reduction Catalyst	Invention patent	3.00	25.33	9.33	8.00
2	Shangluo University — Collagen-Based Surfactant and Preparation Method	Invention patent	3.00	24.67	12.00	7.00
3	Shangluo University — A Simple Metal Powder Compaction Die	Utility model patent	2.00	21.00	9.00	7.00
4	Guilin Aerospace — Citrus Huanglongbing Visualization Platform V1.0	Software copyright	0.50	32.00	10.00	10.00
5	Guilin Aerospace — Real-Time Driving-Behavior Insurance Risk Alert System	Invention patent	1.50	26.00	10.67	8.00
6	Yangtze University — Screw-Drilling Bypass Valve with a Filtering Mechanism	Utility model patent	7.50	21.07	9.47	6.93
7	Yangtze University — A Method for Preparing Regenerated Cement Stone	Invention patent	2.00	25.00	12.00	9.00
8	Yangtze University — Machine Reading Comprehension Intelligent Software V1.0	Software copyright	2.00	33.50	11.50	12.50
9	Guangzhou Maritime — Power-System Resilience Assessment Method and Device	Invention patent	1.00	26.00	11.00	8.00
10	Chengdu Aeronautic — A Method for Dynamically Generating SQL Statements	Invention patent	0.50	26.00	12.00	8.00
11	Dalian Ocean — Universal Drive System for an Unmanned-Vehicle Power Baseboard	Invention patent	1.00	25.00	10.00	9.00
12	Dalian Ocean — AIS Radar Signal Receiving Device	Utility model patent	0.50	20.00	10.00	6.00
13	GRG Banking — Portfolio of 48 Digital-Technology Intangible Assets	Asset portfolio	2609.63	27.12	5.46	9.26
14	Jinfei Kaida — Portfolio of 4 Industrial-Robot Patents	Asset portfolio	73.51	24.36	7.74	8.31
15	Haimo Technologies — Portfolio of 32 Subsea-Metering Patents	Asset portfolio	6727.47	20.00	9.97	7.01

The ranking results should be viewed with care. The market approach, as well as the proposed or negotiated price provided by most of the university pricing benchmarks, depends on the similarity of the valuation input vis-à-vis the benchmark. The income approach also may be more informative for mature assets with identifiable cash flows; the cost approach will be useful for early-stage assets with fewer market or income data points.

4.2. Error Characteristics Across Asset Types

Utility-model patents have relatively low deviations according to all three methods, and with only the 12 university single-asset observations. This is likely because software copyrights' commercial value is more attributable to algorithmic performance, iteration, user scenarios,

and ongoing service capacity than to historical development expenditures alone, the highest cost-approach deviation (32.75%).

Table 3. Mean Relative Deviations by Type of Single Asset (%)

Asset type	Cost approach	Income approach	Market approach
Invention patent	25.43	11.00	8.14
Utility model patent	20.69	9.49	6.64
Software copyright	32.75	10.75	11.25

4.3. Historical-Error Prior Weights

If the overall mean deviations of the 15 observations are used as priors for a subsequent valuation period, these correspond to error reciprocals of 3.978, 9.991 and 12.096 normalizing to weights of 0.153, 0.383 and 0.464 for the cost, income and market approaches respectively. These are historical priors at the method-level, not ex-post optimal weights for a given asset and should be updated with changes in the sample composition.

Table 4. Overall Method Weights Based on 15 Historical Observations

Valuation approach	Mean deviation	Error reciprocal	Prior weight
Cost approach	25.14%	3.978	0.153
Income approach	10.01%	9.991	0.383
Market approach	8.27%	12.096	0.464

The out-of-sample validation is performed by removing each test observation in turn for the computation of the mean error at the method level and the training weight. The resultant weight is then applied to that test case. The present study follows leave-one-out estimation as a standard validation framework, and it is not attempting to make unsupported claims of fusion precision due to the fact that available data reliably preserve relative deviations but not complete signed results of the valuation for all observations.

4.4. Recalculation of Representative Cases and Method Selection

GRG Banking's digital-technology portfolio consists of 48 assets with a reference value of RMB 26.0963 million. By taking full replacement cost (RMB23.74 million) and 20% obsolescence, the cost can be estimated at RMB18.99 million (27.23% deviation). The income estimate is around RMB 27.53 million (5.49% deviation) with first year attributable income of RMB 6.75 million and benefit period of 5 years and a discount rate of 10%. When the commercialization and income attribution are relatively clear, as the case suggests, the income approach dominates.

Haimo Technologies' 32 subsea-metering patents have a disclosed appraised value of RMB 67.2747 million. The replacement cost is RMB65.15 million, the obsolescence rate is 17.5%, and the cost is estimated to be about RMB53.75 million (deviation of 20.10%), while the cost is estimated to be about RMB73.74 million (deviation of 9.61%) based on the stated income scenario. Verifiable anonymous comparables are not used to derive an accurate market estimate since the appraisal report documents the uncertainty of future income and inadequate comparables.

Table 5. Direct Calculation Results for Two Asset-Portfolio Cases

Case	Reference benchmark / RMB 10,000	Cost-approach estimate	Cost-approach deviation	Income-approach estimate	Income-approach deviation
GRG Banking — 48 digital-technology assets	2609.63	1899	27.23%	2753	5.49%
Haimo Technologies — 32 subsea-metering patents	6727.47	5375	20.10%	7374	9.61%

4.5. Robustness and Interpretation of Results

The results should still be proportional to the quality of the data. There are significant differences between the size of the university and listed-company cases, and the stage of commercialization and the type of benchmark used; the three methods are also sensitive to different parameters. It is therefore desirable that in future replication, the source of each parameter, the date, and the rule of ex ante determination should be recorded and stratified samples should be used where possible.

The evidence supports that there are structural differences in method performance, and that using historical error as a starting point, and using weights on top of that error, are objective ways to move forward toward the next step, but not necessarily that fusion is already proven to be superior in all cases. Rolling leave-one-out estimation, time-series cross-validation, paired Wilcoxon tests or bootstrap intervals could be employed to compare out-of-sample performance with increased number of verified transactions.

5. Discussion

5.1. Multi-Method Valuation Is Fundamentally about Information Matching, Not the Number of Methods

A combination of all three approaches does not in itself indicate robustness. The critical question is whether the characteristics of the assets are commensurate with the method used: costs for the traceable early-stage R&D, income for identifiable and stable cash flows, and market for sufficiently comparable transactions. Fusion has meaning only when more than one fusion method is really applicable.

5.2. Adaptive Weights Should Shift from “Ex Post Optimal” to “Ex Ante Usable”

Adaptive weighting should be usable ex ante – not ex post optimal. It may be tempting to select better methods or parameters using the reference price of an asset, but this results in small retrospective errors, without any operational value. The use of historical-sample weighting and leave-one-out training does maintain external applicability, although perhaps at the cost of more conservative estimates.

5.3. Implications for Corporate Technology-Asset Management

The framework can be made actionable by firms having internal technology-asset databases documenting asset types, industries, commercialization phase, base-method estimates, final transaction consideration, and key parameters. The traceable valuation–transaction–error history can then be used repeatedly to update weights by industry or asset type while still maintaining an understandable history for board, financing or asset-transfer decision making.

6. Conclusion and Limitations

In this study, the cost and income approach are compared in a common framework and historical-error-based adaptive weighting is suggested. The 15 observations have mean relative deviations of 25.14%, 10.01% and 8.27% for three prior weights of approximately

0.153, 0.383 and 0.464. There are significant differences in the cost based deviations for software copyrights and the performance of the methods depends on the asset type and the quality of the information.

The framework is based on historical error not test case error and benchmark leakage is avoided via leave-one-out or rolling training. It also differentiates between actual transaction prices, contractual consideration, professional appraisals and proposed prices, and conclusions will remain aligned with benchmark quality.

The study has the following limitations: (1) the number of public transactions is small; (2) the cases being analyzed are not representative of a single type of transaction, as both universities and corporate transactions are included; (3) the signed valuation results are not complete for all 15 observations; (4) the parameters employed are scenario-dependent. Future studies should focus on verified transaction and payment information, and create stratified databases by industry and asset type, and use time-series cross validation, bootstrap techniques, and sensitivity analysis.

The overarching goal is not to find a single best way to incorporate performance feedback and interpretability within a valuation mechanism, but rather to create a replicable performance-feedback system based on an interpretable valuation approach. For multi-method valuation to be an updateable decision tool, it must have transparent weight sources, rules for parameters and definitions of benchmarks.

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