International Journal of Data Envelopment Analysis

Science and Research Branch (IAU)

# A Genetic-DEA Approach to Reveal Property Rights Priorities

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**Abstract**

In this paper we have applied Genetic-DEA modelling to help decision makers improve national economic performance through enhancing intellectual property rights indices. We categorized countries applying a novel classification approach and applied genetic algorithm and data envelopment analysis for modelling the relativity of property rights behavior of nations to their economic productivity. We also present a new concept as the uncertainty factor for priority suggestions to have a confidence factor tailored for each specific country for priority recommendations. The results of our research indicate that rich countries shall let people easy access to loans and fight copyright piracy afterwards. Middle income countries have to first enhance the independency of their judicial system and thenceforth respect intellectual property rights. Subsequently, they need to enhance their political stability. Countries that pay few respects to property rights shall boost judicial independence as the first priority and then advance the protection of physical property rights. Poor countries are advised to enhance registering properties and then focus on the rule of law.

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## 1. Introduction

Intellectual property (IP) rights are the rights given to persons over the creations of their minds. They usually give the creator an exclusive right over the use of his/her creation for a certain period of time. IP is protected in law by, for example, patents, copyright and trademarks, which enable people to earn recognition or financial benefit from what they invent or create. By striking the right balance between the interests of innovators and the wider public interests, the IP system aims to foster an environment in which creativity and innovation can flourish. Hence the final order of IP is to flourish the economy.

Intellectual property rights (IPR) are here to help inventors foster their inventions into wealth. IPR not only gives revenue to inventors but also increases the economic performance of a nation in macro scale. Now, when a country decides to improve its economic performance by enhancing IPR, which areas of IPR determinants shall be focused as high priorities? In an evolutionary point of view, we see nations boost various aspects of intellectual property over time and shape their very own national IP systems. That is why we observe quite different IP systems worldwide, even in developed counties like Japan and the United States. What if we could simulate this evolutionary progress and predict who is more successful in the future? To do this, we follow this logic:

• Property rights are aimed to enhance the national macroeconomic performance. Hence there must be reasonable relationship between PR measurements and macroeconomic indices. Hopefully we observe tight dependency between International Intellectual Property Rights Index (IPRI) and GDP per capita (IPRI report).

• As PR is strongly linked to GPD per capita, determining factors of PR must also have some kind of relation to GDP per capita. This is the exact point of stimulation that nations try to boost their economies by advancing PR components.

GDP estimates are commonly used to determine the economic performance of a country or a region, and to make international comparisons. Hence we can roughly classify if a country is poor, rich or in the middle. The importance of such classification goes back to Maslow's "Hierarchy of Needs" model to determine what the nation's priority is. For example, for a poor country, advancement of rule of law and political stability is far more important than copyright piracy or patent protection. On the opposite side, rich countries seem to give less weight on political stability and rule of law.

Who shall gain wealth trough intellectual property rights? What are the perquisites of doing so? To answer these questions, we present an evolutionary model and simulate the quest of nations enriching the property rights components, including intellectual property rights, towards enhancing economic performance.

The close relationship between property rights and prosperity is a rich vein of this research. Many studies have attempted to explain what makes a country prosperous. It is not only difficult to agree on the definition of prosperity, let alone, but also it is difficult to find the relevant variables to measure it. Talbott and Roll [9] find that enforcing strong property rights is among the main issues to promote growth of GDP per capita. O'Driscoll and Hoskins [7] examine the most relevant economists in history and show that classical economists grasped the importance of private property for development, but as they render this result obviously, it was not emphasized and was abandoned during the majority of the 20th century, only to be revived at the end of the century.

Based on studies about poverty and informal economy, De Soto [2] proposes a theory of development that is grounded in reviving dead capital and transforming it into active capital. His solution for achieving revival is through strengthening

formal property rights. He highlights the socio-economic potential of the poor if they were able to gain property rights: "what the poor lack is easy access to the property mechanisms that could legally fix the economic potential of their assets, so they could be used to produce, secure or guarantee greater value in the extended market. Altogether, he claims that a formal property rights system produces six crucial elements to promote the development of an open society. It fixes the economic potential of assets, integrates dispersed information into one system, makes people accountable, makes assets fungible, allows people to network and protects transactions.

Meinzen-Dick and et al. [6] focus on the importance of property rights for poverty reduction. It is not only an asset to generate income, but it also creates a sense of belonging and stability. Meinzen-Dick and et al. [5, 6] concluded that more secure land tenure for the poor is a way to reduce poverty, as it provides not only income but also an asset to generate it.

An important channel that attempts to alleviate poverty is credit facilities. However, studies are inconclusive about the relationship between financial development and poverty. Singh and Huang researched 37 Sub-Saharan Africa countries from 1992-2006 and conclude that property rights not only reinforce the effect of narrowing inequalities with financial deepening, but the absence of property rights could also be detrimental to the poor.

Ahlerup and et al. [1] added social capital to the institution of property rights as a complement to achieve economic growth. This was also true for Hall and Ahmad who used the World Value Survey to measure trust as a proxy of social capital. They found that political institutions are significant determinants of growth via the property rights channel. Other important externalities of property rights are those related to democracy, empowerment or corruption. Dong and Torgler [3] give us theoretical and empirical evidence of 108 countries from 1995-2006, demonstrating that the effects of democratization on control of corruption depend on the protection of property rights and income equality, thereby creating a virtuous circle.

Last but not least is the important role of property rights in reducing transaction cost through the agency theory. Kim and Mahoney [4] make an interesting comparison of the agency, property rights, and transaction cost theories. While the theories have the same antecedents, property rights theory illustrates its importance as an organizational approach–which has a lot to say for strategic management.

## 2. International Property Rights Index

The International Property Rights Index scores and ranks countries worldwide based on three factors: the state of their legal and political environment, physical property rights, and intellectual property rights. These factors are similarly calculated based on total of ten measured agents. The IPRI was developed to serve as a barometer for the status of property rights across the world. A vast review of the literature on property rights was done in order to conceptualize and operationalize a comprehensive characterization of property rights. Following convention set in place by previous indexes, several experts and practitioners in the field of property rights were consulted to finalize the set of core categories (here-to referred to as "components" or 'sub-indexes') and the items that create the components.

The following are the three core components of the IPRI:
(1)   Legal and Political Environment, LP
(2)   Physical Property Rights, PPR
(3)   Intellectual Property Rights, IPR
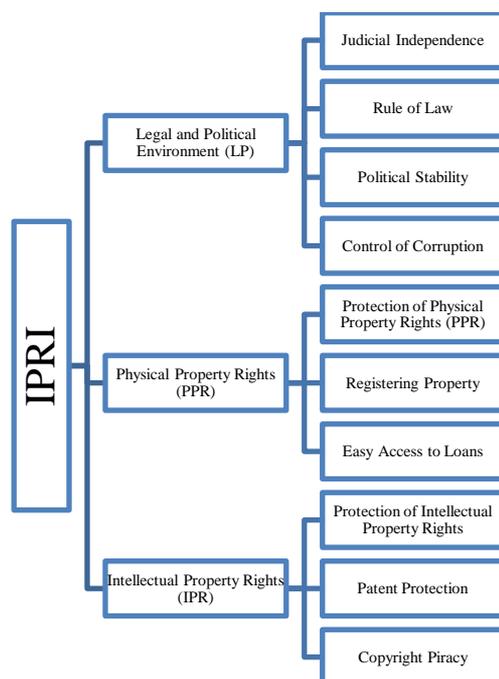
**Figure 1- Structure of IPRI**

The Legal and Political Environment (LP) component provides insight into the impact of political stability and rule of law in a given country. Consequently, the measures used for the LP are broad in scope. This component has a significant impact on the development and protection of physical and intellectual property rights.

The other two components of the index - Physical and Intellectual Property Rights (PPR and IPR) - reflect two forms of property rights, both of which are crucial to the economic development of a country. The items included in these two categories account for both de jure rights and de facto outcomes of the considered countries.

The IPRI is comprised of 10 items in total, grouped under one of the three components: LP, PPR, or IPR. Although numerous items related to property rights were considered, the final IPRI is specific to the core factors that are directly related to the strength and

protection of physical and intellectual property rights. Furthermore, items, for which data was readily available, updated more frequently and in a greater number of countries, were given preference. This was done to ensure that scores were comparable across countries and years.

**3. IPRI and GDP per capita**

The importance of property rights is because of its close relationship to prosperity and wellbeing of nations. Figure 2 shows the relationship between the IPRI scores and GDP/c. Overall, the relationships are strong and significant, with a Pearson coefficient of $r = 0.822$ ($p < 0.01$). In addition, the best-fit curve for this case is a 2nd grade polynomial which improves the coefficient of determination, being $R^2 = 0.7919$.
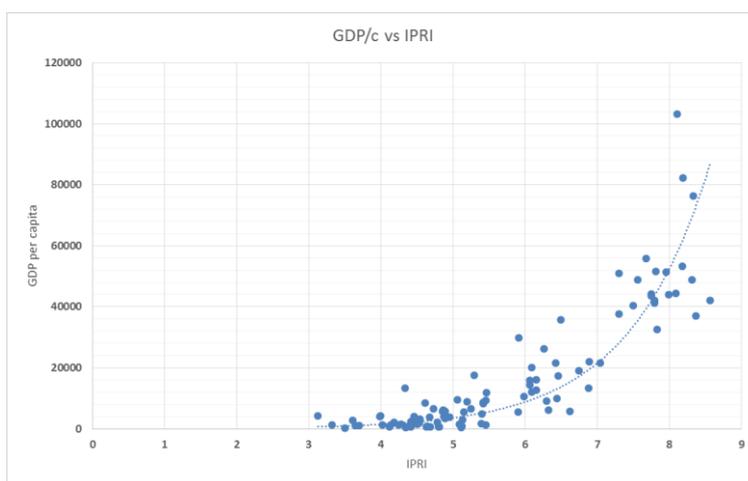
**Figure 2- Relationship between IPRI and GDP per capita**

Figure 2, shows the real data extracted from property rights measurement in 2015 IPRI [8] report and 2015 World Bank report for GDP data. In this figure, countries with high IPRI index have high GDP per capita. This means that, according to Maslow's "Hierarchy of Needs" model, their concerns lies on top layers of this model so, they would likely to have less problems and concerns on legal and political (LP) components. Likewise, countries with very low GDP per capita which typically have low IPRI, would have most of their problems on LP components and few or no priority on intellectual property rights (IPR) components.

## 4. Problem definition

How can we model the impact of IPRI components over GPD? Here we propose an exponential form of equations for GDP estimation based on IPRI components:

$$GDP_{estimated} = \sum_{i=1}^{10} a_i X_i^{b_i}$$

Where $X_1$, $X_2$… $X_{10}$ are IPRI components in the same order shown in Table 1, where $a_i$ and $b_i$ are corresponding weight and exponential factor for each IPRI component.

**Table 1- IPRI Components**

| Component | Category | Designation |
|---|---|---|
| $X_1$ | Legal and Political Environment (LP) | Judicial Independence |
| $X_2$ | Legal and Political Environment (LP) | Rule of Law |
| $X_3$ | Legal and Political Environment (LP) | Political Stability |
| $X_4$ | Legal and Political Environment (LP) | Control of Corruption |
| $X_5$ | Physical Property Rights (PPR) | Protection of Physical Property Rights |
| $X_6$ | Physical Property Rights (PPR) | Registering Property |
| $X_7$ | Physical Property Rights (PPR) | Easy Access to Loans |
| $X_8$ | Intellectual Property Rights (IPR) | Protection of Intellectual Property Rights |
| $X_9$ | Intellectual Property Rights (IPR) | Patent Protection |
| $X_{10}$ | Intellectual Property Rights (IPR) | Copyright Piracy |

Each set of $\{a_i|b_i\}$ produces an estimation of GDP with an inaccuracy behaviour defined as below:

$$Error = \frac{|GDP_{estimated} - GDP_{real}|}{GDP_{real}}$$

Hence we can define the error function for any assumed set of countries as below:

$$Error_{Cluster\ of\ contries}$$
$$= \frac{1}{Number\ of\ Countries\ in\ Cluster}$$
$$\sum_{Cluster\ of\ contries} \frac{|GDP_{estimated} - GDP_{real}|}{GDP_{real}}$$

To specify country sets, we need to cluster the above information. We applied fuzzy c-means clustering (FCM) for this purpose. Hence, data is fed into Matlab software using fuzzy tools package. In FCM clustering method, first we must specify the number clusters. Fuzzy clustering result depends on two factors: The first factor is the number of clusters and the second is the initial value of clusters. These two factors determine the accuracy of clustering. An

innovative – rather simple – algorithm is provided in this study to determine the number of clusters. FCM is a recursive algorithm by itself however; we have wrapped up a simple algorithm over FCM to increase the number of clusters one by one with high number of iterations leading to high number of close cluster sets. The algorithm continues to increase the number of clusters until it reaches a certain error limit between close clusters. Here the error limit of 1e-5 was considered. Results of this algorithm consist of four regions shown in Figure 3.

Looking at this figure, we can easily spot two large gaps in the horizontal line, one gap around IPRI of 5.5 and the other one around IPRI 7.2. We simply choose these two borderlines to distinguish low, middle and high IPRI countries. Also as seen in Figure 3, a small strip is highlighted in green as poor countries with low IPRI.

**Figure 3- Country segmentation**
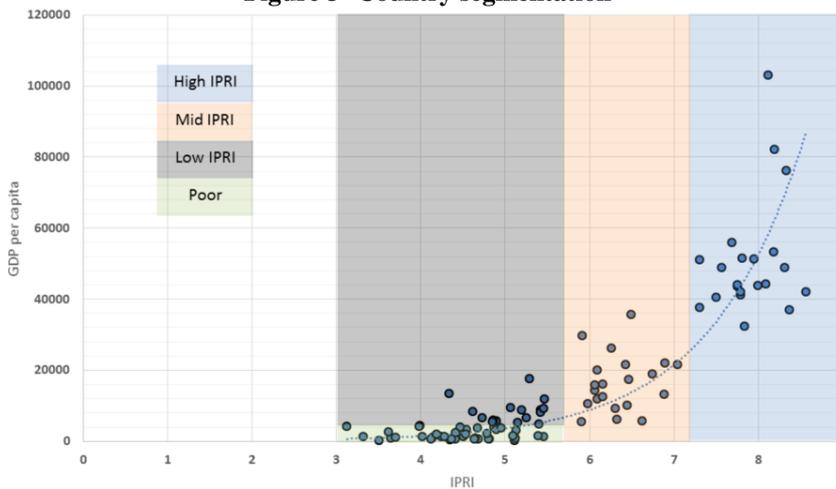
We use genetic algorithm to find the best $\{a_i|b_i\}$ solution for defined set of countries.

Here is the definition of a single chromosome in our approach:

| $a_5$ | $a_6$ | $a_7$ | $a_8$ | $a_9$ | $a_{10}$ | $b_5$ | $b_6$ | $b_7$ | $b_8$ | $b_9$ | $b_{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|

Chromosome definition for High IPRI countries (excluding LP components)

| $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ | $a_7$ | $b_1$ | $b_2$ | $b_3$ | $b_4$ | $b_5$ | $b_6$ | $b_7$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

Chromosome definition for Poor countries (excluding IPR components)

| $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ | $a_7$ | $a_8$ | $a_9$ | $a_{10}$ | $b_1$ | $b_2$ | $b_3$ | $b_4$ | $b_5$ | $b_6$ | $b^7$ | $b_8$ | $b_9$ | $b_{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

Chromosome definition for Middle and Low IPRI countries (including all components)

And for each set of countries, the aim of the algorithm would be to minimize the error as shown below:

$$Min(Error_{Cluster\ of\ countries})$$

## 5. Analysis Results

As mentioned before we have four clusters of countries which are displayed in Table 2:

**Table 2- Country Clusters**

| Cluster | Number of Courtiers | Number of cells per Chromosome | Criterion |
|---|---|---|---|
| High IPRI | 21 | 12 | IPRI>7.2 |
| Mid IPRI | 21 | 20 | 5.5<IPRI<7.2 |
| Low IPRI | 31 | 14 | IPRI<5.5 and GDP/c>2000 |
| Poor Low IPRI | 24 | 14 | GDP/c<2000 |

Genetic algorithm is implemented using country GDP per capita and IPRI data. Parameter tuning is applied for following GA attribute for each cluster of data. Four parameters are tested with four different levels in 16 different experiments. Hence 16×4 different experiments are applied and fed into Minitab Taguchi analyzer. Results are displayed in Figure 4, 5, 6 and 7. Taguchi Experiment design is displayed in Table 3. After running 64 different experiments proposed by Minitab software and many "Try and Errors", we concluded a set of common attributes with equal or better results proposed by Taguchi parameter tuning labelled as "Common Attributes" in Table 3.
 GA attributes for all clusters are displayed in Table 4 and the algorithm results are presented in Table 5a and 5b. In Table 5 numbers less than 0.01 are assumed as zero. Ranked based fitness scaling, scales raw

scores based on the rank of each individual instead of its score. The rank of an individual is its position in the sorted scores. Uniform selection chooses parents using the expectations and number of parents. When there are constraints, the mutation function randomly generates directions that are adaptive with respect to the last successful or unsuccessful generation. The mutation chooses a direction and step length that satisfies bounds and linear constraints. Heuristic crossover returns a child that lies on the line containing the two parents, a small distance away from the parent with the better fitness value in the direction away from the parent with the worse fitness value. The algorithm stops if the average relative change in the best fitness function value over Stall generations is less than or equal to Function tolerance.

**Table 3- Taguchi Experiment parameters and levels**

| Level | Fitness Scaling | | Fitness Selection | Mutation | | Crossover |
|---|---|---|---|---|---|---|
| **1** | Rank | | Uniform | Adaptive | | Heuristic |
| **2** | Proportional | | Stochastic | Uniform1 | 0/01 | Two Point |
| **3** | Top | | Roulette | Uniform2 | 0/1 | Scattered |
| **4** | Shift Linear | | Tournament | Uniform3 | 0/05 | Arithmetic |

**Figure 4- Taguchi analysis for High IPRI**



**Figure 5- Taguchi analysis for Mid IPRI**
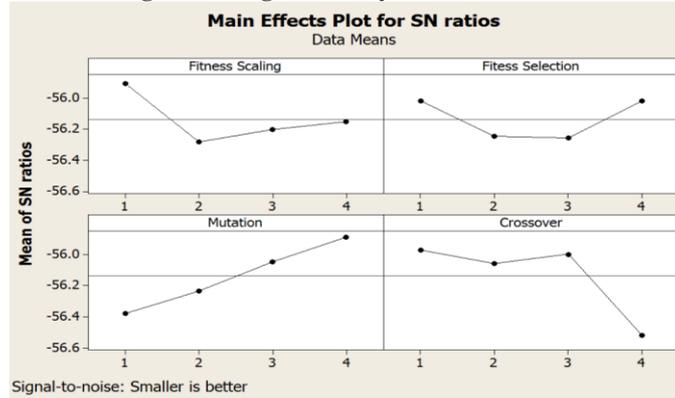


**Figure 6- Taguchi analysis for Low IPRI**
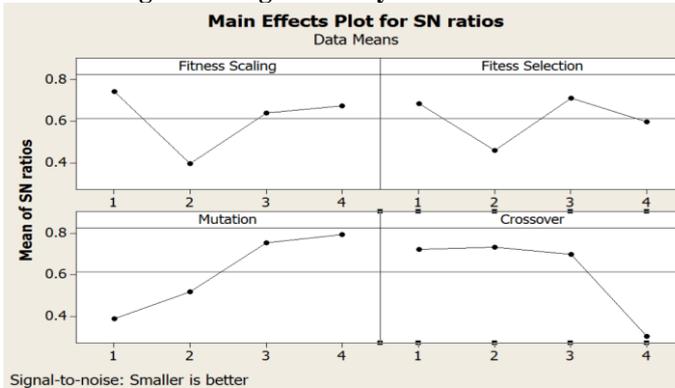
**Figure 6- Taguchi analysis for Poor Low IPRI**



**Table 4- GA attributes**

| Genetic Algorithm Attribute | Common Attributes | Taguchi Results | | | |
|---|---|---|---|---|---|
| | | High | Mid | Low | Poor |
| Population size | 200 | 200 | 200 | 200 | 200 |
| Fitness Scaling | Rank | Shift Linear | Rank | Rank | Rank |
| Fitness Selection | Uniform | Uniform | Tournament | Rolette | Rolette |
| Mutation Function | Adaptive feasible | Uniform 0.05 | Uniform 0.05 | Uniform 0.05 | Uniform 0.05 |
| Crossover | Heuristic | Heuristic | Heuristic | Two Point | Heuristic |
| Stall generations | 50 | 50 | 50 | 50 | 50 |
| Function tolerance | $10^{-6}$ | $10^{-6}$ | $10^{-6}$ | $10^{-6}$ | $10^{-6}$ |
| | Taguchi Error | 15% | 31% | 30% | 32% |
| | Common Error | 15% | 29% | 29% | 31% |

**Table 5a- GA Analysis results**

| Cluster | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ | $a_7$ | $a_8$ | $a_9$ | $a_{10}$ | *Err* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| High | | | | | 1.5 | 871 | 1092 | 2208 | 2019 | 796 | 15% |
| Mid | 27 | 0 | 20 | 0 | 0.2 | 0 | 0 | 95 | 0 | 0 | 29% |
| Low | 17 | 98 | 55 | 27 | 9 | 18 | 99 | 75 | 20 | 2 | 29% |
| Poor | 1.57 | 2.2 | 2.7 | 5.4 | 10.6 | 1.67 | 16 | | | | 31% |

**Table 5b- GA Analysis results**

| Cluster | $b_1$ | $b_2$ | $b_3$ | $b_4$ | $b_5$ | $b_6$ | $b^7$ | $b_8$ | $b_9$ | $b_{10}$ | *Err* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| High | | | | | 0 | 0 | 1.5 | 0 | 0 | 1.1 | 15% |
| Mid | 2.97 | 0 | 1.82 | 2.88 | 0 | 0 | 0 | 2.59 | 0.35 | 0 | 29% |
| Low | 3.3 | 0 | 0 | 0 | 3.1 | 0 | 0 | 2.2 | 0 | 2.7 | 29% |
| Poor | 0.36 | 2.8 | 1.66 | 0 | 2.1 | 3.3 | 0.6 | | | | 31% |

High IPRI: We have all valid weights for fitness function $GDP_{estimated}$ while, $b_7$ and $b_{10}$ are the dominant exponents. Hence corresponding dominant IPRI components are $X_7$ and $X_{10}$ with priorities proportional to exponents. We can apply the same logic to the next three experiments. The summary of this analysis is displayed in Table 6.

**Table 6- GA Analysis Summary**

| Cluster | | High Priority Components | Priority |
|---|---|---|---|
| High IPRI Countries | $X_7$ | Ease of Access to Loans | 1 |
| | $X_{10}$ | Copyright Piracy | 2 |
| Mid IPRI Countries | $X_1$ | Judicial Independence | 1 |
| | $X_8$ | Protection of Intellectual Property Rights | 2 |
| | $X_3$ | Political Stability | 3 |
| Low IPRI Countries | $X_1$ | Judicial Independence | 1 |
| | $X_5$ | Protection of Physical Property Rights | 2 |
| | $X_{10}$ | Copyright Piracy | 3 |
| | $X_8$ | Protection of Intellectual Property Rights | 4 |
| Poor Low IPRI Countries | $X_6$ | Registering Property | 1 |
| | $X_2$ | Rule of Law | 2 |

## 6. Comparison with Regression

We also tried to fit $GDP_{estimated}$ to $GDP_{real}$ data, using standard regression algorithm. The results are given in Table 7. In this table numbers less than 0.01 are assumed as zero.

**Table 7a- Regression Analysis results**

| Cluster | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ | $a_7$ | $a_8$ | $a_9$ | $a_{10}$ | *Err* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| High | | | | | 0 | 0 | 3e7 | 0 | 1.5e9 | 0 | 26% |
| Mid | 28045 | 0 | -14792 | 317 | -53109 | 38173 | 0 | 0 | 1692 | 2e12 | 27% |
| Low | 1078 | -311 | 0 | 0 | -6408 | -268 | -184 | 8122 | 0 | 0 | 32% |
| Poor | 0 | 0 | -205 | -11 | 0 | 73 | 2007 | | | | 25% |

**Table 7b- Regression Analysis results**

| Cluster | $b_1$ | $b_2$ | $b_3$ | $b_4$ | $b_5$ | $b_6$ | $b^7$ | $b_8$ | $b_9$ | $b_{10}$ | *Err* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| High | | | | | 22 | 7.2 | -3.8 | 20 | -5.4 | 13 | 26% |
| Mid | 0 | -2.7 | 0 | 2 | 0 | 0 | -1.1 | 22 | 1.2 | -12 | 27% |
| Low | 1.4 | 1.5 | 23 | 14 | 0 | 1.7 | 1 | 0 | 5.6 | 19 | 32% |
| Poor | 12 | 19 | -375 | 3.1 | 9 | 1.5 | 0 | | | | 25% |

As seen in Table 7a and 7b, the fitness accuracy which can be interpreted as error function is slightly better in Mid and Poor clusters, slightly worst in Low cluster and almost double in High cluster of our data. The average error for GA algorithm is 26% where in regression algorithm is 27.5%. So, there is no meaningful difference in accuracy. More over regression algorithm is free to range weights and exponents to achieve best result. Hence with negative coefficient assigned to dominant components, for example $X_7$ in table 6a and 6b, no meaningful interpretation can be concluded.

## 7. DEA Analysis

As seen on Table 5, Genetic Algorithm approach offered a helpful indication towards top priorities for each cluster of

countries to enhance their GDP through enhancing property rights components. However, we face uncertainty when opting a country to recommend or policy making in this regard since GA introduced a general guide for cluster of countries with an uncertainty factor named error function or *Err* which signals the need of further analysis.

Data envelopment analysis (DEA) was originated in by Charnes et al. [10] and the first DEA model was called the CCR (Charnes, Cooper and Rhodes) model. DEA is a linear programming based technique for measuring the relative efficiency of a fairly homogeneous set of decision making units (DMUs) in their use of multiple inputs to produce multiple outputs. It identifies a subset of efficient 'best practice' DMUs and for the remaining DMUs, the magnitude of their inefficiency is derived by comparison to a frontier constructed from the 'best practices'. Efficient DMUs are identified by an efficiency score equal to 1, and inefficient DMUs have efficiency scores less than 1. Efficiency score can be a criterion for ranking inefficient DMUs, but this criterion cannot rank efficient DMUs.

We choose DEA methodology as the second step analysis for focusing into clusters and uncover hidden relationships among IPRI components as inputs and GDP as output for the following reasons:

- DEA approach takes into consideration the complex nature of the system and accommodates multiple inputs and multiple outputs in a single analysis.
- DEA does not assume nor require a judgment on the relative importance or weights of inputs and outputs.
- DEA application can be used to set specific input and output targets for inefficient institutions based on the observed performance of best practice institutions in the peer group. It focuses on optimal, not average, performance and sets input and output targets that are practical and attainable.
- DEA helps identify the "efficient reference group" or specific best practice countries for the focus countries.

To this end, we first apply DEA over all countries and use all IPRI components as inputs and GDP as output. Table 8 displays the top ten countries ranked by the relative efficiency as the objective. Not surprisingly, United States and China Stand in the efficient frontier and other countries stay far behind them. This means that US and China have the most efficient mechanism to enhance their GDP through IPRI components relative to other countries. Hence they are most justified to advise GA IPRI priorities recommendation.

**Table 8-Top 10 DEA Efficiency**

| Country | Efficiency |
|---------|------------|
| United States (USA) | 1 |
| China | 1 |
| India | 0.30 |
| Japan | 0.26 |
| Italy | 0.24 |
| United Kingdom (UK) | 0.22 |
| Germany | 0.22 |
| Nigeria | 0.19 |
| Russia | 0.17 |
| France | 0.17 |

As seen in Table 8, other countries reveal efficiencies far behind the frontiers. Hence we take US and China as special cases out of the list and recalculate efficiencies. The result is displayed in Table 9. Now in the absence of US and China, Indonesia, Japan and India lie in the efficient frontier, i.e. *Objective = 1*, and other countries follow them closely. Although, we are not ranking efficient countries but this objective indicates how much a country is justified to follow GA IPRI recommendations.

**Table 9-Top 10 DEA Objective Excluding USA and China**

| Country | Efficirncy |
|---------|------------|
| Indonesia | 1 |
| Japan | 1 |
| India | 1 |
| Italy | 0.92 |
| Venezuela | 0.880 |
| Germany | 0.87 |
| Russia | 0.86 |
| UK | 0.85 |
| France | 0.73 |
| Brazil | 0.72 |
| Nigeria | 0.64 |

We take one step forward and calculate relative efficiencies in each cluster of countries. Here we exclude US and China again and apply the same IPRI components as we used in GA analysis in each cluster.

**Table 10-Top Ten DEA Efficiency by IPRI Clustering (excl. US and China)**

| High | | Mid | | Low | | Poor | |
|------|------|-----|------|-----|------|------|------|
| Country | Efficirncy | Country | Efficirncy | Country | Efficirncy | Country | Efficirncy |
| Japan | 1 | Italy | 1 | Indonesia | 1 | Bangladesh | 1 |
| Germany | 0.87 | Turkey | 0.91 | Venezuela | 1 | Greece | 1 |
| UK | 0.85 | Spain | 0.79 | India | 1 | Vietnam | 0.975 |
| France | 0.74 | Saudi Arabia | 0.65 | Brazil | 1 | Peru | 0.942 |
| Canada | 0.41 | Taiwan | 0.38 | Russia | 1 | Algeria | 0.892 |
| Australia | 0.36 | Israel | 0.34 | Mexico | 0.75 | Czech Republic | 0.813 |
| Netherlands | 0.20 | Poland | 0.3 | Nigeria | 0.64 | Portugal | 0.809 |
| Switzerland | 0.18 | South Africa | 0.2 | Argentina | 0.55 | Romania | 0.798 |
| Belgium | 0.13 | Malaysia | 0.2 | Pakistan | 0.33 | Ukraine | 0.619 |
| Sweden | 0.12 | Chile | 0.17 | Thailand | 0.25 | Ecuador | 0.608 |

Having the results of DEA analysis in Table 10, we can conclude that Japan, Italy, Indonesia, Venezuela, India, Brazil, Russia, Bangladesh and Greece shall follow GA analysis recommendation regarding their associated IPRI cluster. Other countries are recommended to follow GA analysis results based on *Err* in Table 6 and efficiency ratio, i.e. *Objective* in Table 10.

Here we can define an uncertainty factor :

$$U_{Country} = (1-ERR_{Cluster})\times Efficiency_{Country}$$

For example, Germany shall follow the results of Table 6 with the uncertainty factor:

$U_{Germany} = (1\text{-}Err_{High}) \times Efficiency_{Germany}$ which is $(1\text{-}0.15) \times (0.87) = 0.74$

The above definition of uncertainty factor is based on uniform distribution of error in reach cluster. We can also define a better and more sensible definition of uncertainty based on the assumption of normal distribution of error function in each cluster. In this case we can consider *1-Err* as the standard deviation and calculate the uncertainty as:

$U_{Country} = 2 \times$ *(area of normal distribution from 0 to Efficiency_{Country} with 1-ERR_{Cluster} as the standard deviation)*

Here, $U_{Country}$ would be 1 i.e. completely certain for countries in the efficient frontier. We can calculate $U_{Country}$ for other countries using standard normal distribution tables.

For example, $U_{Germany} = 0.88$, $U_{Turkey} = 0.90$, $U_{Mexico} = 0.71$ and $U_{Vietnam} = 0.97$

## 8. Conclusions

In the context of evolution theory, high IPRI countries, which are also all considered as rich countries, shall let people *easy access to loans* and then avoid *copyright piracy*. Here are some countries in the middle that are grown up both in economic and property rights aspects and may be interested in catching up economically. These countries take quite different prescription; they have to first enhance the *independency of their judicial system* and then *respect intellectual property rights*. Afterwards, they need to enhance their *political stability.* Our analyses results indicate that countries that are not considered as poor but still have low property rights environment shall also boost *judicial independence* as the first priority and then advance *the protection of physical property rights*. Although such courtiers have much to do for their property rights, they still have money to spend and have enough space to think of innovation based development. Hence, after taking care of judicial system and physical property right,

they need to first *fight copyright piracy* and then boost *intellectual property rights protection*. Countries at the bottom which are considered as poor are advised to enhance *registering properties* and then focus on the *rule of law*.

High IPRI countries which are also rich in terms of GDP/c are better fitted to our model. That means, such countries have little uncertainty gaining wealth through heightening property rights. As we can see, in Table 6, they just have to give money to creative people that need protection from copyright piracy. We see more uncertainty, technically as double, in other clusters.

Taking our study into the fuzzy side, we look at the subsequent error for each cluster. We took IPRI components as inputs of economic engine and evaluated the efficiency of each country using data envelopment analysis. US and China were two countries with very high IPRI efficiency relative to other countries. This indicates that US, which has high IPRI and high GDP has efficiently utilized IPRI components to enhance the economic performance and shall follow GA recommendation to perform even better. China which does not have a high IPRI ranking is also showing a perfect IPRI efficiency related to other countries. This indicated the China's adequate quality of property rights policy making and suggests this country to follow GA recommendation foe Low cluster.

We also presented a new concept as the uncertainty factor for policy/priority suggestions introduced in this study. Hence we not only have recommendations for each cluster of countries but also present a confidence factor tailored for each specific country.

## 9. Further studies

In this study we applied genetic algorithm and data envelopment analysis to model the relativity of property rights behavior of

nations to their economic productivity. We separated countries based on IPRI and GDP/c hence other eloquent clustering are also applicable. For example, we can choose countries based on geographical, political or even cultural basis. Also, we can have the same study using IPRI data for different years for better analysis. This could reduce the uncertainty level of our model. For example, Oil economies or African nations may have their own pattern of priority. We can even apply multi-clustering and analyze a single country based of its membership to different clusters. In this case, combination of GA with PSO may give impressive results.

# References

[1] Ahlerup, P., Olsson O and Yanagizawa, D. 2009. "Social capital vs institutions in the growth process" European Journal of Political Economy.Vol.25, pp.1-14.

[2] De Soto, H. 2000. El misterio Del capital: Por qué el capitalismo triunfa en occidente y fracasa en el resto Del mundo. NY: Basic Books, London: Bantam Press/Random House, Lima: El Comercio.

[3] Dong B., & B. Torgler, 2011. "Democracy, Property Rights, Income Equality, and Corruption.Nota Di Lavoro. Global Challenges Series. FondazioneEni Enrico Mattei.

[4] Kim, J. & J.T. Mahoney, 2005. "Property Rights Theory, Transaction Costs Theory and Agency Theory: an Organizational Economics Approach to Strategic Management" Managerial and Decision Economics.Vol 26:223-242. DOI: 10.1002/mde.1218.

[5] Meinzen-Dick, R., 2009 Property rights for poverty reduction? Economic and Social Affairs DESA Working Paper No. 91. ST/ESA/2009/DWP/91. December.

[6] Meinzen-Dick, R., P. Kameri-Mbote & H. Markelova 2009, Property Rights for Poverty Reduction. In von Braun et al. pp.227-235

[7] O'Driscoll Jr G. P. and L. Hoskins, 2003. "Property Rights: The Key to Economic Development" Policy Analysis #482, pp.1-17, Aug 07.

[8] Sary Levy-Carciente, "International Property Rights Index Report", http://internationalpropertyrightsindex.org/, 2015

[9] Talbott, J. & R. Roll, 2001. "Why Many Developing Countries Just Aren't" The Anderson School at UCLA, Finance Working Paper No. 19-01. Nov.13, 2001. [http://ssrn.com/abstract=292140]

[10] Charnes, A., Cooper, W.W., Rhodes, E., 1978. Measuring the efficiency of decision making units. European Journal of Operational Research. 2, 429-444.