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Research Article

Philippines' Fluidity of Innovation from 2001 to 2021: Interpretations and Implications

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ABSTRACT

While innovation is generally accepted as one of the drivers of economic growth, most innovation metrics are qualitative and have a relatively lesser impact on policymaking than their quantitative counterparts. With this challenge, this paper presents another quantitative metric: the Fluidity of Innovation applied in the Philippines from 2001 to 2021. The study analyses data from public government reports and reputable private entities using the contextualized Reynolds Number from fluid mechanics. The findings reveal a significant transformation in the Philippines' innovation, moving from a laminar (smooth and predictable) to a turbulent (rapid and complex) phase; this indicates the country has a growing capacity to cater to rapid development in technology such as Artificial Intelligence and Quantum Computers. Since the Philippines is leaning towards a turbulent flow of innovation, some technology will be felt as Radical Innovation instead of Disruptive Innovation across the industries that allow the labor force to experience empowerment rather than a complete layoff. This research contributes to the broader understanding of innovation's role in the Philippine economy and fiscal policies, particularly those for innovation and technology.

Keywords*: Fluidity of innovation, Innovation, Laminar, Macroeconomics, Open innovation, Philippines, Turbulent*

Introduction

Innovation is universally acknowledged as a pivotal driver of economic growth (Kumar & Sundarraj, 2018). However, measuring and managing its significant yet intangible impact is challenging, especially for nations like the Philippines, where innovation plays a crucial role in shaping economic dynamics.

Countries have utilized qualitative and quantitative tools to assess innovation (Gault & Soete, 2022). While qualitative metrics offer rich narratives, they often lack the objectivity necessary for robust analysis, reflecting Peter Drucker's famous adage, "You cannot manage what you cannot measure." On the quantitative side, metrics such as patent counts and

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research and development expenditures provide tangible indicators (Dutta, Soumitra. Editor. et al., 2023).

However, these measures offer a limited view and overlook innovation activities' broader impacts and effectiveness (Funk, 2021; Park et al., 2023); thus, innovation metrics should breakthrough to a more univariate metrics similar as to how GDP can represent a broad macroeconomic perspective of a country. There are multiple attempts in creating a univariate metrics in the literature such as the work of Pugliese et al. (2019) that attempts to quantify innovation by treating it like a network, it is able to be congruent with the triple helix nature of innovation (Momeni et al., 2019) but this attempt fails to consider the open innovation nature in the industry (Bigliardi et al., 2020).

The one that best captures the intangibility and dynamism of innovation is the metric **Fluidity of Innovation**. This univariate metric can determine how a country treats innovation by understanding if innovation flows laminarly (siloed innovation, as shown in Figure 1) or turbulently (open innovation, as depicted in Figure 2) inside a country by quantifying innovation' flow' within a nation.

Such an approach is advantageous because it captures the pipe flow analogy, the dynamic and fluid nature of innovation within a country (Ulhøi, 2021), and the spatial production for innovation (Olah & Alpek, 2021). With this nature of innovation, Radziszewski's (2020) approach of contextualizing fluid mechanics was appropriate.

If applied, public officials can better understand the rate of innovation the country can handle, guiding fiscal policymakers on whether they should accept specific policies and programs that will hasten or dampen a country's technological advancement. The existence of this univariate metric now raises the question, "*How does the Philippines manage the diffusion of innovation (With the emphasis on the process, not on the innovation or technology only)? Does innovation flow inside the country in a laminar or turbulent fashion?*". Thus, this paper attempted to identify the Philippines' Innovation Fluidity.

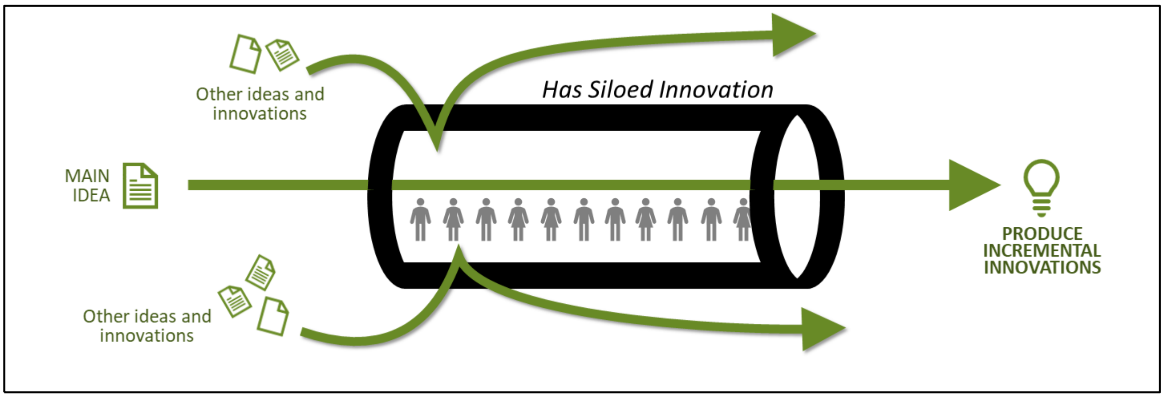

Figure 1. Laminar Flow: Ideas incubate and mature poorly as they pass the environment too fast (Siloed Innovation).

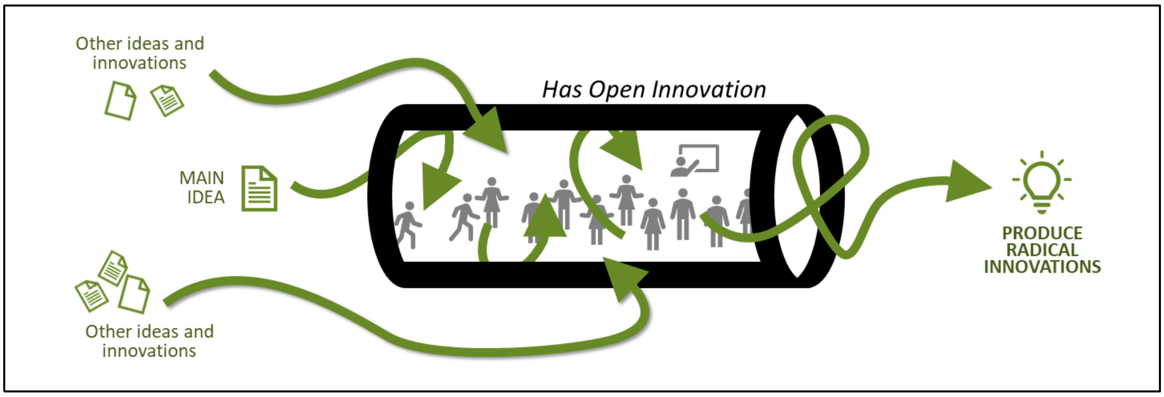

Figure 2 Turbulent Flow: Ideas incubate and mature greatly as they "swirl" with the environment (Open Innovation).

METHODOLOGY
Data Approach
Rationale

This descriptive paper intends to determine the type of innovation fluidity in the Philippines; thus, this paper will utilize innovation fluid mechanics. The original contextualized Reynold Formula is compatible with being used for an organization at the governmental level (Radziszewski, 2020). The formula is also reliable as it employs reputable independent innovation variables as input variables while having **Rï** result correlated with other innovation indices, as shown in Figure 3 and Figure 4 below.

Since the nature of innovation is dynamic and intangible (Trivellato et al., 2021), this approach is also advantageous because it captures the dynamic and fluid nature of innovation within a country, mirroring the transition from laminar to turbulent flow in fluid dynamics; hence, this novel approach promises a more nuanced and accurate depiction of innovation processes, akin to how the Reynolds number captures the intricacies of fluid flow.

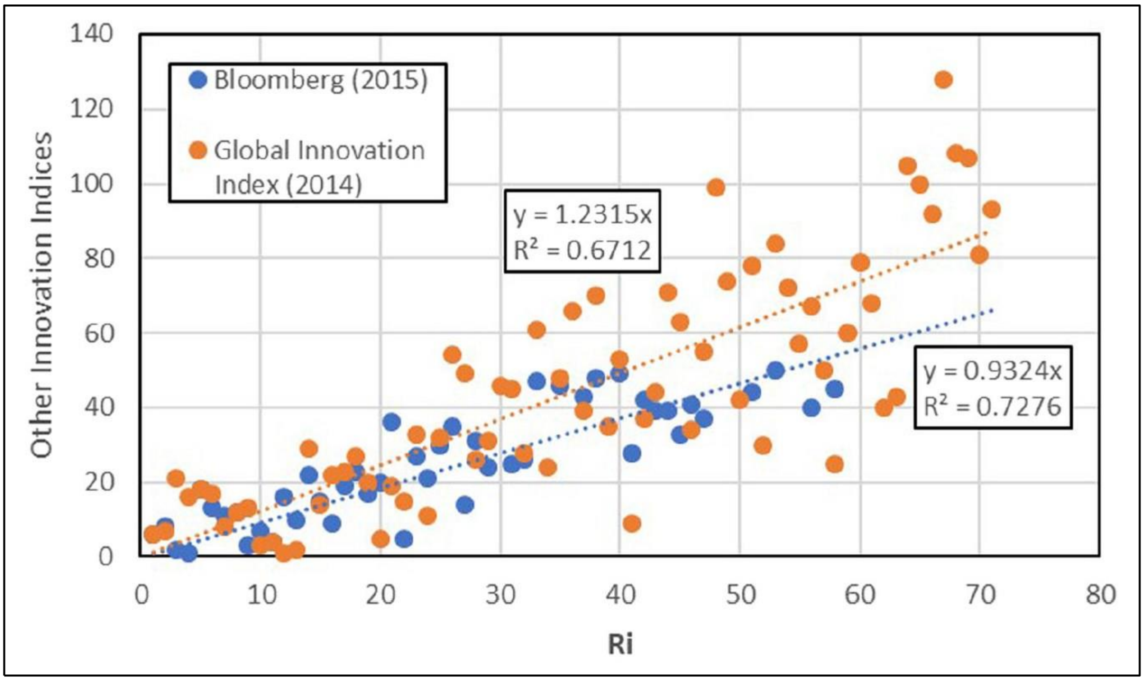

Figure 3. There is a very high correlation between Rï results and other innovation indices (Radziszewski, 2020)

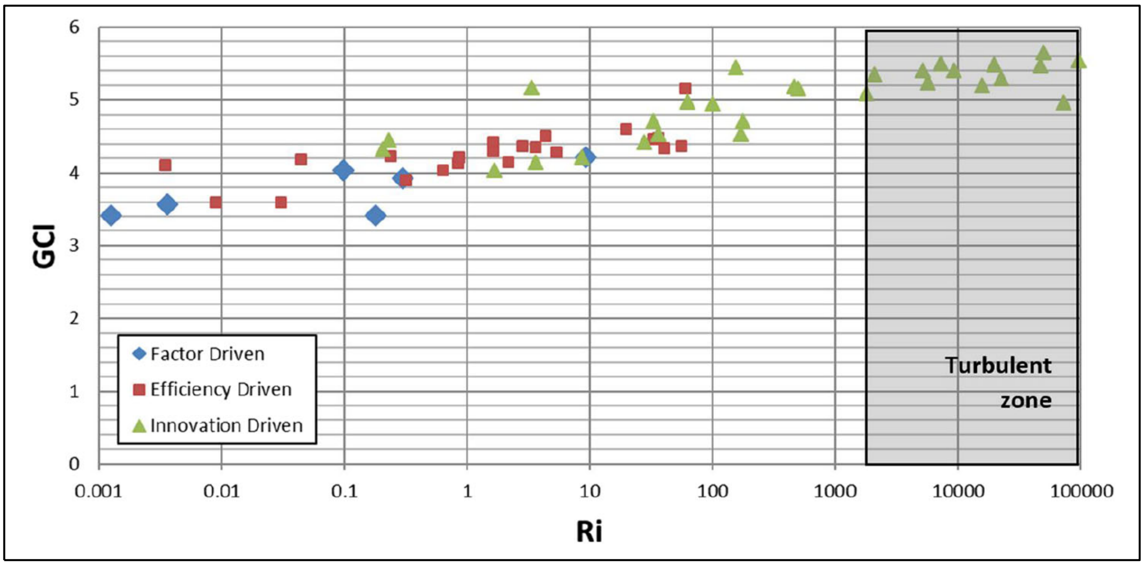

Figure 4 There is a very high correlation between Rï results and Global Competitiveness Index [GCI] (Radziszewski, 2020)

Formula

The formula for the Fluidity of Innovation was the contextualized Reynold's formula (Radziszewski, 2020), which is presented below.

$$R_{\text{ï}} = \frac{4\,\rho\,P\,L}{\mu\,\Delta p\,\pi\,D^2}$$

Where:

Rï = Reynold's Innovation Fluidity Level

ρ = **Density** of innovations [Total number of Intellectual Property in a country divided by its population].

P = **Power** for innovators [Research and Development Expenditure divided by Gross Domestic Expenditure].

L = **Length** of innovation momentum [Total population of researchers and research technicians].

μ = business **Viscosity** or restrictions to communications, interactions, and interdependence.

Δp = **Losses** of innovation momentum [Total gov't expenditures divide by Gross Domestic Product]

D = **Distance** of innovators in terms of social relationship, not physical location. [can be Corruption Perception Index]

π and the constant **4** are holdovers from the pipe flow analogy and are considered here as scaling factors.

Since Rï is mainly a univariate innovation metric drawn from the field of study of Fluid Mechanics rather than a statistical predictive model, the multicollinearity test was deemed not imperative to this paper.

Calculations

The yearly Rï was computed to establish the trend of the Philippines's innovation fluidity in a descriptive fashion.

Monetary values are taken at current prices; no adjustment or conversion was needed since these input variables are not directly compared to another year. The output variable, which is the Rï, is virtually a single giant ratio that technically comprises ratios; thus, comparing yearly Rï is mathematically acceptable.

Research Tools

For accurate calculation and comprehensive data visualization, the researcher of this paper utilizes R-Studio for the calculation of the **Rï** while assuring P-Values were observed when applicable. Furthermore, R-Studio was considered reputable and reliable among the community of researchers (Giorgi et al., 2022; Selva Babu et al., 2022; Tseng et al., 2024).

Data Gathering

The data are gathered from private reports and the government's accessible database through public channels, such as the Philippine Statistics Authority and Euromonitor Internationals. All input data spans from 2001 to 2021. Since data are sparse, some are drawn from while others are converted to fill some data gaps. The details are as follows:

Density [ρ] is the Innovation Incidence per Capita, which is an absolute scale and is defined by the number of patents and trademarks applied for by residents each year divided by the country's population. Since one can argue that the population is an active population, this paper has utilized populations in the Philippines ranging from ages 15 to 60.

Power [P] is expressed in the percent of GDP spent in RnD. Since Gross Domestic Product, Gross Domestic Income, and Gross Domestic Expenditure are technically the same and interchangeable, this paper utilized Gross Fixed Capital Formation in Intellectual Property Product divided by the Government's Final Consumption Expenditure to determine how much percentage the Philippine government placed in Research and Development.

Length [Δp] is an absolute scale and is defined by the number of researchers and research technicians in each country. This paper deems the data from the World Bank (UNESCO, 2024) erroneous as it claims there are only more or less 200 researchers per million in the Philippines, which is obviously incorrect since some large universities in the Philippines comprise hundreds if not thousands of professorial researchers, let alone the researchers in the corporate and industries. With that, the data was sourced from the Philippine Statistics Authority under the occupational group Research, Research Technicians, and professions with similar endeavours.

Viscosity [μ] is a measure of ease of doing business and can range from 0 (easy to do business) to 1 (very hard to do business). Although the World Bank records ease of doing business per country, it is mostly a rank, not a score. This paper will utilize the Index of Economic Freedom (The Heritage Foundation, 2024) instead, as it captures the essence of

Viscosity since the scope encompasses all possible thinkers and not just a single entity.

In fluid mechanics, **Losses [Δp]** refer to the reduction in mechanical energy of a fluid as it moves through a system (Javaherchian et al., 2023). In the context of the fluidity of innovation in a country, the loss is the percentage of GDP representing government expense (Radziszewski, 2020).

Distance [D] is a measure of relationship closeness or farness. This variable was considered since the level of social trust was claimed to have affected the level of innovation (Sabol & Winton, 2022; Steinbruch et al., 2021); in elaboration, a society that is relationally distant from one another will not share ideas, and innovation seldom incubates in a collaborative manner; if people are close to one another, they openly share ideas and incubate innovations in a collaborative manner.

The value of this variable (Distance) ranges from 0 (perfectly no distrust) to 1 (perfectly in distrust). In the context of national fluidity of innovation, this variable can be represented with the inversion of the Corruption Perception Index [CPI] since the presence of increased levels of trust is associated with the absence of corruption (Poertner & Zhang, 2023; Van de Walle & Migchelbrink, 2022).

Data Analysis

Types of Innovation

This paper will define the type of innovations shown in Table 1.

Output Variables Analysis

The Rï values were then interpreted using the standard fluid mechanics explanation, as shown in Table 2, to determine how fluid innovation transpires inside the Philippines and the possible implications for the country.

Input Variables Analysis

After understanding the country's state, the input variables were analyzed to understand which is much more critical for the Philippines. The Random Forest method was utilized since this machine learning method helps pinpoint variables when the subject has complex, non-linear relationships between variables (Orlenko & Moore, 2021). In Random Forest, the importance of variables is generally measured through metrics like Mean Decrease in Impurity [MDI] or Mean Decrease in Accuracy [MDA]. MDI is based on the decrease in node impurity (Gini impurity in classification, variance in regression) when splitting on the variable, while MDA measures the decrease in model accuracy when the values of a variable are permuted; both are used to gauge the importance of variables in the model (Degenhardt et al., 2019).

Table 1 Types of Innovation according to Impact

	Impact to Market	**Impact to Labor Force**
Incremental Innovation	Improves Current Market	Assist Workers
Radical Innovation	Introduces New Market	Empowers Workers
Disruptive Innovation	Obsoletes Old Products and Services	Layoffs Workers

Table 2. Interpretation of Rï values

Country's $R_{ï}$ Value	**Corresponding fluidness of innovation in the country**
$0 < R_{ï} < 2000$	Laminar
$2000 < R_{ï} < 4000$	Transitioning State
$4000 < R_{ï}$	Turbulent

RESULT & DISCUSSION

Output Variable (Rï)

As shown in Table 3, innovations and ideas in the Philippines are in a state of laminar flow, meaning most produced innovations are at the lowest level, which is incremental innovations. Also, since the innovation in the country could diffuse is in turbulent manner, the country is not capable of catering drastic technological changes, as disruptive innovation could cause layoffs (Fossen & Sorgner, 2019). Fortunately, it is noticeable in Figure 5 that the Philippines is experiencing a development in terms of how fluid the ideas transpire in the country, projecting the Philippines may experience a turbulent innovation flowing in the future.

Table 3. Philippine's Rï and the corresponding State of Innovation Fluidity

Year	Philippine's Rï Values	Gross Domestic Diffusion of Innovation
2001	9.587	Laminar
2002	14.214	Laminar
2003	14.580	Laminar
2004	51.314	Laminar
2005	82.439	Laminar
2006	119.522	Laminar
2007	170.440	Laminar
2008	136.695	Laminar
2009	110.952	Laminar
2010	65.977	Laminar
2011	133.313	Laminar
2012	299.397	Laminar
2013	262.640	Laminar
2014	471.130	Laminar
2015	526.463	Laminar
2016	1,103.067	Laminar
2017	1,056.280	Laminar
2018	1,316.102	Laminar
2019	1,431.755	Laminar
2020	750.957	Laminar
2021	1,361.172	Laminar

Input Variables

Results from the Random Forest approach, as shown in Table 6, claim that 'Length (L),' 'Density (d),' and 'Losses Δp' are the most influential variables, as they contribute more to the increase in Mean Squared Error when their values are permuted. The 'Node Purity' measure also reflects their importance in the model's decision trees. This suggests that the Philippines should invest in these three determinants of innovation fluidity to have a much more turbulent environment.

An interesting observation of the Philippines' fluidity of innovation is its congruence with Post-Keynesian economic principles (Balakrishnan & Milberg, 2019). The very strong positive correlation of the innovation variable Losses (L) towards **Rï**, as shown in Table 4, suggests that expenditures the Republic of the Philippines makes have a positive effect on how innovation flows in the country.

Another pattern that this paper confirms is the recurring low correlation and coefficient of determination value for the input variable 'Power (P)' as shown in Table 4 and Table 5. This phenomena may be explained in the findings of Harada (2018) that R&D investment of the government are not immediately felt in the economy due to path-dependent effects towards endogenous innovations.

Table 4. Correlation Table for Input Variables towards the Output Values (Rï)

Correlations	**Rï**	**Remarks**
Density	0.910***	
Power	0.193	Recurring very low correlation
Length	0.944***	
Viscosity	-0.787***	
Losses	0.746***	
Distance	-0.776***	

Table 5. Coefficient of Determination Table for Input Variables towards the Output Variable (Rï)

Coefficient of Determination (R^2)	Rï	Remarks
Density	0.829***	
Power	0.037	Recurring very low R^2
Length	0.891***	
Viscosity	-0.621***	
Losses	0.557***	
Distance	-0.603***	

Table 6. Random Forest Importance Table for Input Variables towards the Output Variable (Rï)

Random Forest Importance	Increase in Mean Squared Error	Importance by Node Purity
Density	11.152890	1,026,334.42
Power	4.296360	79,673.92
Length	11.223535	1,106,759.73
Viscosity	9.675235	909,915.03
Losses	9.997688	1,167,297.09
Distance	7.455006	284,008.31

RECOMMENDATIONS

The Philippine government should pursue to have innovation flow in the country in a turbulent fashion; having a nation handling innovation in a turbulent fashion will benefit the nation as more radical innovations are produced.

Viewing the effects of the turbulent diffusion of innovation towards each economic sectors, the supply side of the economy is much more resilient to changes brought by technological advancements and innovation as businesses pioneer changes (Radziwon & Vanhaverbeke, 2024; Razumovskaia et al., 2020) while the demand side is much more open to radical products and services as consumers become more accustomed to innovations such as the paradigm shift from traditional to online acquisition of goods and services (Suherlan & Okombo, 2023); in addition, since a turbulent diffusion of innovation implies that the general trust level of the people are high, consumers are more open to utilize radical platforms of goods and services (Zhao et al., 2023).

On the government side, the Philippines can have a stable unemployment rate even with the introduction of dramatic technological changes as workers become more familiar with innovation (Fossen & Sorgner, 2019) – having disruptive innovation impacts the labor market as radical innovation instead; in line with Okun's Law, a stable unemployment rate could lead to a stable GDP growth rate. Similar to this paper, the findings of Balaceanu et al. (2019) also show that investment in technology and innovation development influences the unemployment rate.

In order to achieve this, the Philippines should support an Open Innovation [OI] setup which is characterized as sourcing ideas and innovation outside the organization (Isomäki, 2018), and since innovation transpires in a quintuple helix model (Mineiro et al., 2021; Yazıcı, 2023), OI should be present to the sectors of the economy mainly the households, business, and financial intermediaries.

Table 7. The macroeconomic effect to a country when innovation flows laminarly or turbulently.

	When Innovation Flows Laminarly	When Innovation Flows Turbulently
Usual Workplace	Siloed Innovation	Open Innovation
Usual Output and Patents	Incremental Innovation	Radical Innovation
Labour Force	Highly susceptible to Disruptive Innovation	Much immune to Disruptive Innovation
Consumer Behaviour	Prefers traditional products.	Welcomes radical products

Should the public administrators and leaders prefer to focus on the input variable of **Rï** to make innovation turbulently flow in the country, the most appropriate the government can perform is to have strong support in teaching and publishing research in senior high schools and colleges similar to other countries to increase the number of researchers per capita (Length) and increase the likelihood of patents per capita (Density), especially for students and professors under the STEM programs. Expansionist monetary policies are also desirable when appropriated to lend private entities to borrow capital to facilitate their respective endogenous innovations (Harada, 2018).

Lastly. Although focusing on the 'Length (L),' and 'Density (d),' protrudes the country to a good **Rï**, the government should not be lenient in keeping the good level of Distance (ρ) since diffusion of innovation in social networks is hampered if people generally do not trust most things (Buskens, 2020).

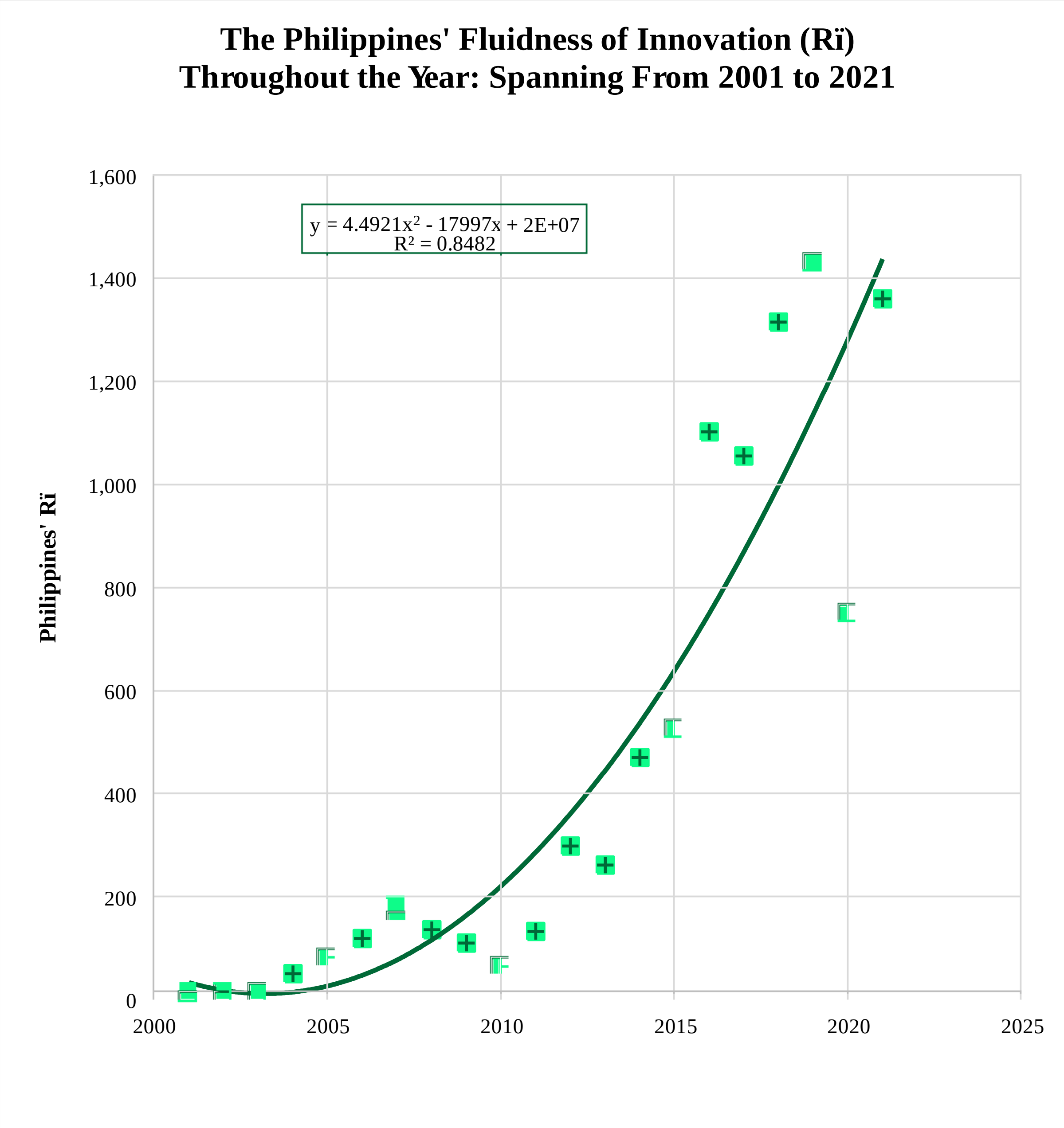

Figure 5. The Philippines' Fluidness of Innovation (Rï) Throughout the Year: Spanning From 2001 to 2021

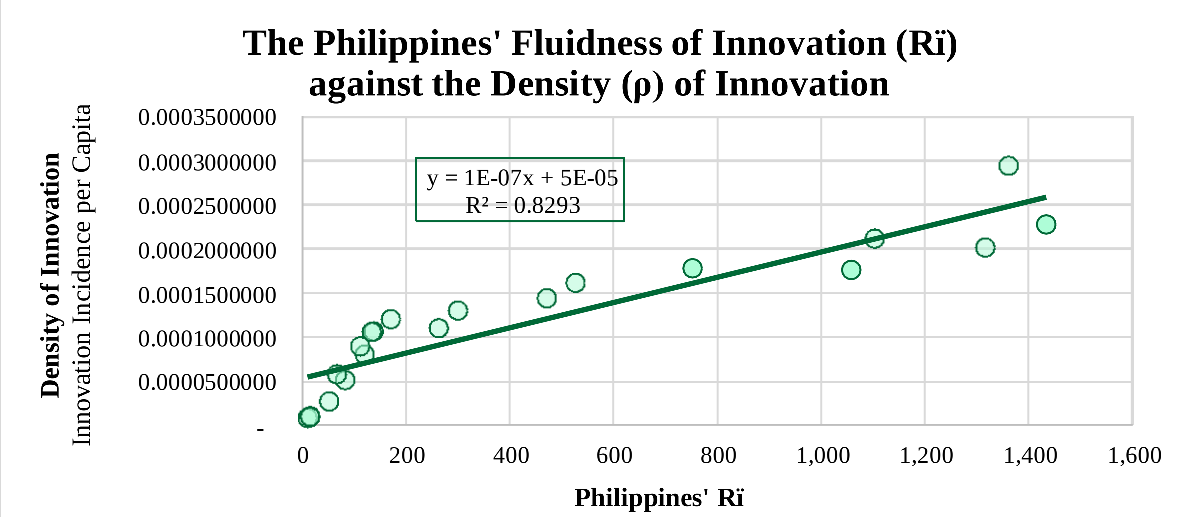

Figure 6. Philippines 'Fluidness of Innovation (Rï) against its subcomponent Density (ρ)

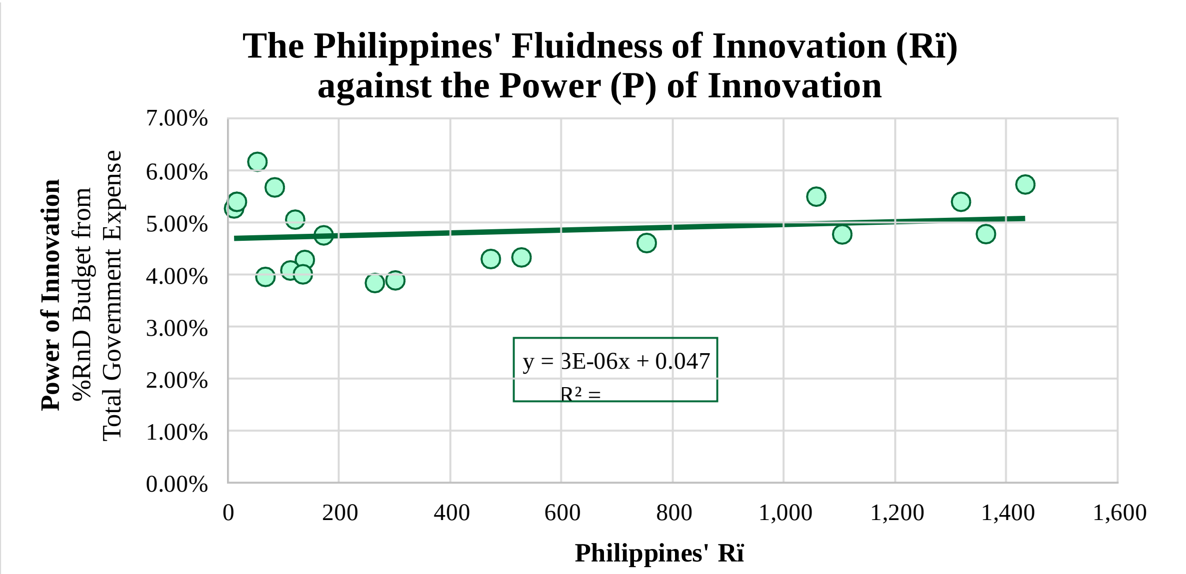

Figure 7. Philippines 'Fluidness of Innovation (Rï) against its subcomponent Power (P)

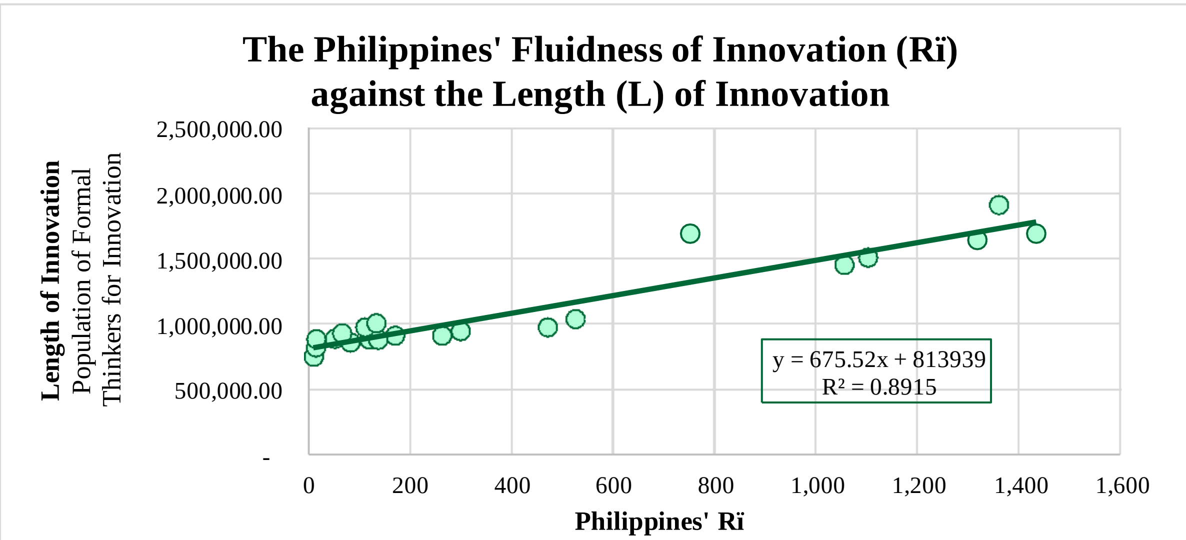

Figure 8. Philippines 'Fluidness of Innovation (Rï) against its subcomponent Length (L)

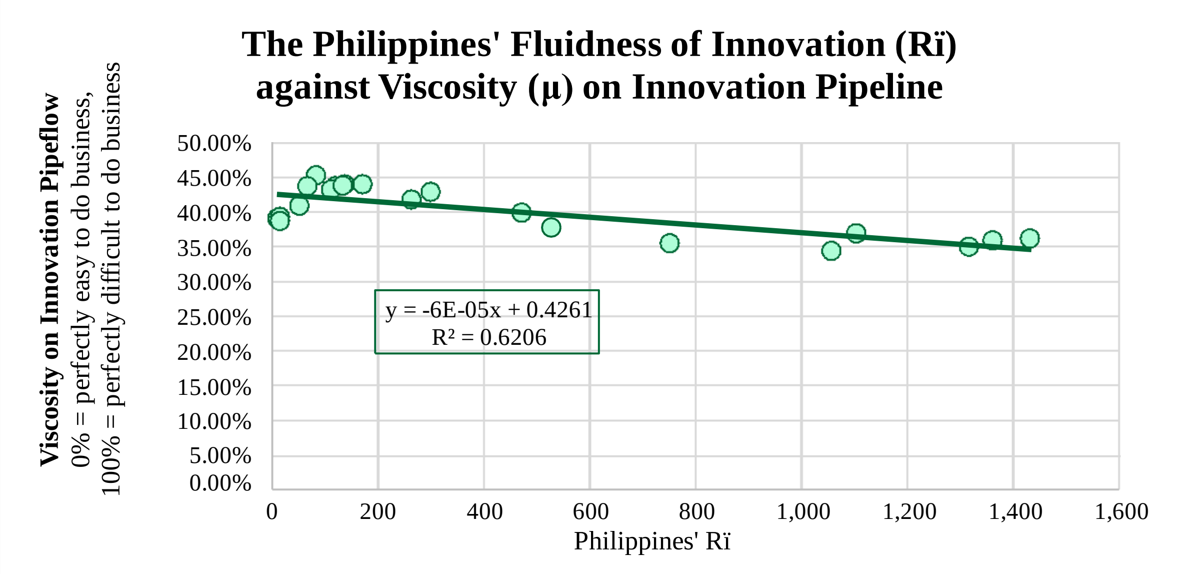

Figure 9. Philippines 'Fluidness of Innovation (Rï) against its subcomponent Viscosity (μ)

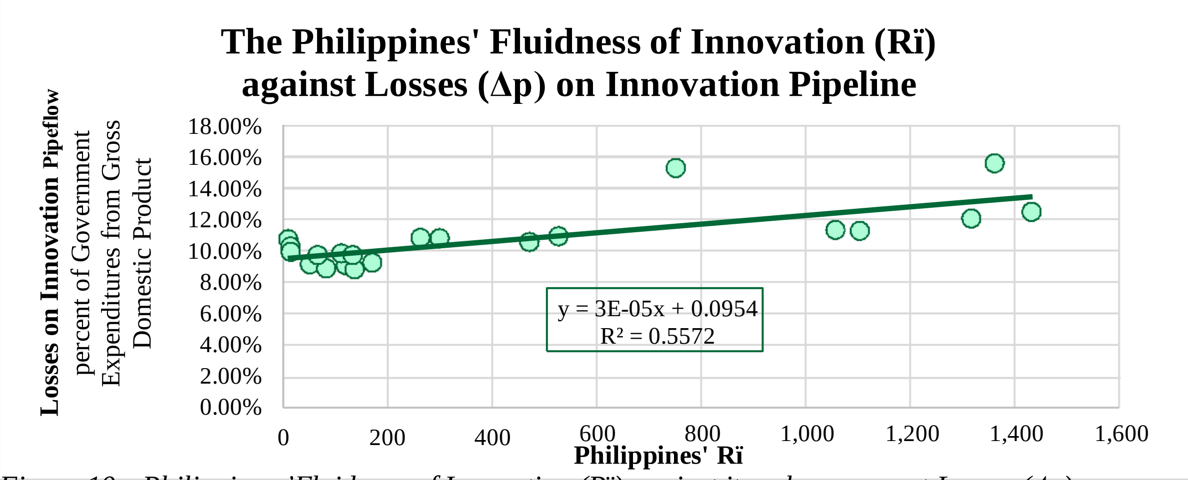

Figure 10. Philippines 'Fluidness of Innovation (Rï) against its subcomponent Losses (Δp)

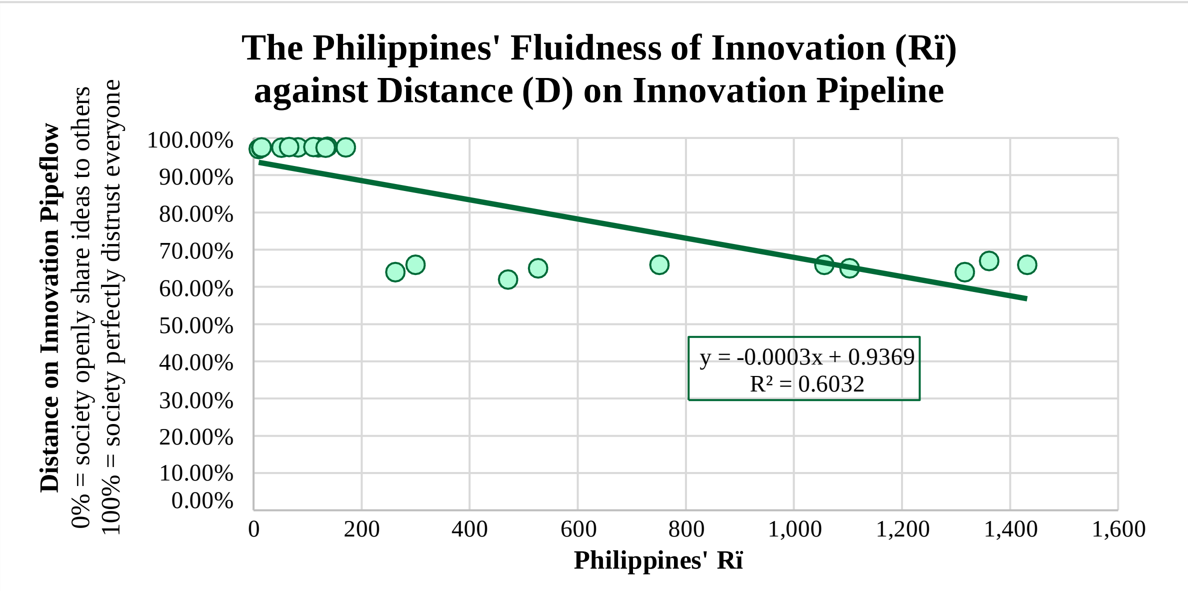

Figure 11. Philippines 'Fluidness of Innovation (Rï) against its subcomponent Distance (D).

CONCLUSION

The task of monitoring a country's innovation performance is increasingly complex, with a burgeoning array of metrics, each demanding its own analysis. This study demonstrates a compelling congruence between the World Bank's assessments and our results on **Rï** fluidity, suggesting that a quantitative approach to measuring a nation's innovation fluidity can potentially replace more qualitative methods. Such an approach might prove more efficient and accessible for local governments, given the general availability of the required data.

This paper has introduced another univariate innovation metric that monitors how innovation flows inside the country treated as an aggregate observance, with these results and findings on how fluid the Philippines can handle innovations.

Future Studies

The significance of the **Rï** values, particularly in the range of 2000 to 4000, where innovation transitions from laminar to turbulent, warrants further investigation to fully understand its implications.

This methodology, applied to the Philippine context, opens the door for similar studies in other countries. Assessing their levels of innovation through this lens could provide valuable insights and contribute to a broader understanding of global innovation dynamics.

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