**On Knightian Uncertainty and Energy Infrastructure: A New Measure and a Global Approach**

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*Abstract*

This paper construct a novel index that measures the insurability of economic activity within a country. Increases in that index can be interpreted as decreases in the presence of Knightian uncertainty. Consistent with economic theory, increases in that index tend to predict increases in the development of energy infrastructure, including renewable electricity generation. These results have policy implications. They imply that removal of policy-induced uncertainty from the energy infrastructure permitting process can accelerate the development of that infrastructure.

1. **Introduction**

Economists have understood the importance of a distinction between unquantifiable uncertainty and quantifiable risk ever since Frank Knight’s seminal *Risk, Uncertainty, and Profit* in 1921. To date, however, much of the literature on energy infrastructure, including on renewable energy, focuses on quantifiable risks rather than unquantifiable uncertainty. This paper is an attempt to fill that gap. It proceeds in three parts.

In the first, it develops a novel index of the insurability of economic activity within a given country. Increases in that index can be interpreted as declines in the aggregate presence of Knightian uncertainty within the country’s economy.

In the second, it uses that novel index to predict country-level outcomes with regards to the development of energy infrastructure. Consistent with economic theory, increases in that index predict an increase in the energy-intensiveness of economic activity. They also predict increases in the generation of electricity from renewable sources.

A third section considers policy implications. At least in the United States, some of the Knightian uncertainty that confronts prospective investment in renewable energy infrastructure comes from policy-created settings, like the permitting process. These results imply that the removal or mitigation of uncertainty from those settings can increase the development of energy infrastructure without harming many stakeholders.

1. **A Novel Index of Insurability and Knightian Uncertainty**

Contemporary economists, like Erbas and Sayers (2006), have used non-life insurance premiums as a share of Gross Domestic Product to study the insurability of risk and the presence of Knightian uncertainty. The use of insurance data builds on the argument of Frank Knight (1921). According to Knight (1921), insurability indicates the possibility of quantifying a risk. If a future outcome can be insured, it stands to reason, then it must be a quantifiable risk rather than an unquantifiable uncertainty. It follows that increases in the insurability of economic activity indicate a decline in unquantifiable uncertainty. Put differently, one could interpret rises in insurability as indications that a larger share of unknown future outcomes have ceased to be unquantifiable uncertainties and been effectively “turned into” quantifiable risks. And that, by construction, represents a decline in the presence of unquantifiable “Knightian” uncertainty.

That forms the basis for intuition behind the use of non-life insurance premiums as a share of GDP to proxy for Knightian uncertainty’s absence in Erbas and Sayers (2006). They interpret an increase in that number as evidence of a decrease in Knightian uncertainty. “In general,” they write, “it is plausible to postulate that higher uncertainty in a country implies lower insurability.” They then add that experimental evidence on individual-level decision making is consistent with this interpretations of their aggregate insurance data.

But the use of non-life insurance premiums as a share of GDP has a conceptual problem, if it is to be interpreted as an index of insurability. *Ex ante* it is impossible to know whether country-level variation in the supply of insurance or demand for it is driving the variation. Yet only the supply of insurance is consistent offers a concept consistent with the insurability of economic activity, or the absence of Knightian uncertainty in the economy. That’s because insurability is about the availability of insurance for economic activity, rather than the use of insurance. If a risk *can* be insured, according to Erbas and Sayers (2006) and Knight (1921), then insurability is present and Knightian uncertainty is absent. But whether a risk *is* in fact insured is a function of things like consumer preferences for risk as well as the underlying availability of insurance, or insurability. Yet the insurance data used in Erbas and Sayers (2006) to measure insurability address the extent to which risks *are* insured. That’s a problem for any interpretation of the Erbas and Sayers (2006) insurance-based data as an indicator of insurability per se.

Imagine two countries with identical insurance markets. In each, the economy itself is identical. And the availability of insurance on economic activity does not vary. In one, people are very risk-averse. In the other, people are risk-neutral. You’d expect higher insurance premiums as a share of GDP in the risk-averse country. But there is no actual variation in the availability of insurance or in Knightian uncertainty. The variation in insurance premiums as a share of GDP is instead driven by demand-side risk preferences. You can imagine the same thought experiment with trust replacing risk-aversion as the source of variation in demand-side preferences. Even with identical insurance suppliers, where citizens trust less, you’d expect more insurance transactions as a share of GDP. As in the first example, however, there is no variation in the availability of insurance or in Knightian uncertainty within the economy. The problem is that variation in demand for insurance as well as the variation in the country-level supply of insurance is driving the observed variation in insurance transactions.

Data on country-level preferences for risk and trust, however, allow a solution that aligns better aligns the concept of insurability from Knight (1921) with empirical data and the goals of Erbas and Sayers (2006). That solution involves combining the data on non-life insurance premiums as a share of GDP with data on economically relevant preferences from the Global Preferences Survey. These data are on country-level preferences for things like risk and trust. Described in Falk et. al (2018), the data of the Global Preferences Survey are available for download on the Internet. Collected from over 80,000 individuals in 76 counties, the survey collects a rich set of information about each participant. As a whole, the survey covers around 90 percent of the world’s population and income. By construction, it is designed to allow an apples-to-apples comparison of preferences between countries.

In the country-level data on preferences for risk and trust in Falk et. al. (2018), then, lies a solution to the supply-and-demand problem that vexes the insurance data from Erbas and Sayers (2006). That’s because it allows one to plausibly remove much of the demand-side variation in a country’s non-life insurance premiums as a share of GDP. That variation is removed through a linear regression of the Falk et. al. (2018) country-level variables for risk preferences and trust on the World Bank’s country-level data on non-life insurance premiums as a share of GDP (World Bank, 2023c). The residual variation from that regression is then interpreted as an indication of the supply of insurance, or the insurability of economic activity. It becomes a variable, *R*, that you can interpret as the supply of insurance, or insurability.

This stripping out of the demand-side variation makes a difference. If one looks simply at the insurance data, for instance, Bangladesh ranks as the country with the highest level of Knightian uncertainty (i.e., its level of non-life insurance premiums as a share of GDP is the lowest). If one strips out the effect of preferences, however, it is Egypt (i.e., its level of *R* is the lowest). China is a case-in-point that proves instructive. In many accounts (e.g., Taleb and Blyth 2011), autocracies like China shift the distribution of economic risks away from small but frequent fluctuations towards rarer “Black Swan” events that have large impacts and are inherently harder to predict. Such “Black Swan” events comport well with the concept of unquantifiable Knightian uncertainty. And in a rank-order of 73 countries, where higher values indicate less Knightian uncertainty, China drops ten places, from 37 to 27, when you remove the influence of preferences on non-life insurance premiums as a share of GDP. The only other country that experiences a drop of similar magnitude and direction is another country, Hungary. That’s another country with a relatively autocratic government for its level of GDP. Hungary drops from a rank of 34 down to 21 when one adjusts non-life insurance premiums as a share of its GDP for preferences for risk and the trust in the country. These results offer some reassurance that the adjustment of the World Bank data with the Falk. et. al (2018) preference data is creating a variable that captures the type of Knightian uncertainty that it’s intended to capture. After all, if accounts like Taleb and Blyth (2011) are to be believed, autocracies have higher levels of Knightian uncertainty than tends to meet the eye. And that is what this process for turning data on non-life insurance premiums as a share of GDP into a measure of insurability to serve as a proxy for Knightian uncertainty indicates. China and Hungary each end up characterized as having a higher level of Knightian uncertainty than would be visible from insurance transactions.

The demand-side adjustment appears to matter relatively less among countries indicated as having less Knightian uncertainty. For instance, set of five countries indicated as having the least amount of Knightian uncertainty – Canada, South Africa, the United States, Venezuela, and South Korea – is the same by either measure. But South Africa and Canada switch places, with Canada underperforming South Africa when looking only at raw insurance data but outperforming when removing demand-side factors. If your intuition was that Canada’s economy has less Knightian uncertainty than South Africa’s, that result comports with it.

Table 1 (at the end of the paper) lists each of the 73 countries in the sample that combines the economic preference data from Falk et. al. (2018) with the World Bank’s insurance data. It ranks each country when using both the raw data on non-life insurance premiums as a share of GDP as well as the *R* variable that strips out the influence of preferences on the insurance data. As mentioned earlier, higher rank-order values indicate the relative absence of uncertainty. Table 1 also lists the raw values for each variable. One interpretation of *R* is that it is a truer indicator of the supply of insurance, or availability of insurability, that economists like Erbas and Sayers (2006) have characterized as a proxy Knightian uncertainty’s absence.

1. **Applying the Index**

The question then becomes whether this novel index of insurability and Knightian uncertainty predicts country-level energy outcomes. At least on some metrics, the answer is yes.

The chart below plots the *R* variable along with a measure of energy consumed per dollar of GDP from the World Bank. The energy variable is the kilograms of oil equivalent used per $1,000 of GDP, adjusted for purchasing power parity (World Bank, 2023b). The data shown are for the year 2015, the latest year for which all the data used in this section’s calculations are available. The data are available for a sample of 25 countries.



Figure 1. Insurability and Energy Consumed per $1,000 of GDP

Economic Insurability Index (*R)*

Kilograms of oil equivalent per $1,000 of GDP

In a simple regression of *R* on the energy per $1,000 of GDP variable, the correlation is statistically significant at the 5% level. The relationship is not trivial in magnitude: an increase of 1.0 in R corresponds to an increase of 15 kilograms of oil equivalent. That’s about as big of a difference as exists between the energy-intensities of France and the United States. The absence of Knightian uncertainty appears, then, to facilitate the development of energy infrastructure, even once you factor out the absence of Knightian uncertainty’s overall impact on economic activity. That factoring out happens through the built-in adjustment of energy consumption for GDP in the World Bank’s measure of kilograms of oil equivalent per $1,000 of GDP.

Figure 2 is a repetition of the same exercise, but with a measure of a country’s increase in electricity generation from renewable sources per capita from 2010 to 2015 in lieu of energy consumption per $1,000 of GDP. The underlying unit of electricity generation from renewable sources, from World Bank (2023a), is the kilowatt—hour (kWH). The change in that unit from 2010 to 2015 was calculated and, to adjust for population size, then divided by the World Bank’s data on population in 2015 (World Bank 2023d). That is the quantity shown on the vertical axis.



Figure 2. Insurability and Growth in Renewable Electricity

Economic Insurability Index (*R*)

Per capita change in renewable generation (kWH), 2010 to 2015

A country’s level of insurability (i.e., *R)* in 2010 is a strong predictor of how much it increased its electricity generation from renewable sources over the next five years from 2010 through 2015. A simple regression of *R* on the per capita change in the amount of energy generated from renewables over the next five years is statistically significant well below the 5 percent level. The magnitude of the regression output implies that a 1.0 unit increase in *R* increases the amount of electricity generated from renewable energy sources by 124 kWh over a five-year period. Given that much of the economic cost of any green transition in the U.S. would center around the generation of renewable electricity (e.g., Fitzgerald and Mulligan 2023), this is an outcome that may be of particular interests to policymakers in the U.S.

Interpretations of these correlations, for now, are best-understood as predictive rather than necessarily causal. A task for future research is to address the causal directions at play with the sophistication that strong causal claims demand. For now, the safest interpretation of the data is that increases in *R* tend to predict increases in the energy-intensity of GDP and in the generation of electricity from renewable sources. An equivalent interpretation is that declines in Knightian uncertainty tend to foreshadow increases in the energy-intensity of the economy, including increases in energy that arrive in the form of new electricity from renewable sources.

1. **Policy Implications**

The apparent role of decreases in Knightian uncertainty in predicting the development of energy infrastructure matters for policymakers. The permitting process in the U.S. is a case-in-point. As argued in Loyola (2023), energy infrastructure in the United States is vexed by Knightian uncertainty from the permitting process. These results offer something of an empirical validation of that argument. They document that the type of Knightian uncertainty that the permitting process plausibly creates really does decrease energy infrastructure. And among the likely symptoms of this are the reliance on equity financing for infrastructure in the U.S.

A point of contrast that underscores the avoidable nature of the uncertainty now in the infrastructure permitting process comes from the FDA’s process for the approval of new pharmaceutical drugs. Jorring et. al. (2023) made the economic case for a new financial instrument, known as an “FDA hedge,” that pays off in the event that a drug fails to get FDA approval. Such an instrument would encourage investment in pharmaceutical drugs by allowing drug developers to hedge out the financial risks associated with non-approval. These instruments will soon be trading in an over-the-counter market.[[1]](#footnote-1) If this market clears and does not display the trading irregularities that Hassett and Zhong (2017) characterize as evidence of Knightian uncertainty, then the characteristics that render FDA approval a quantifiable risk rather than an unquantifiable uncertainty will offer a model for how infrastructure permitting in the U.S. can be reformed so that it becomes an insurable risk. Those are likely to be actionable steps not unlike some of the reforms suggested in Loyola (2023). For instance, the FDA’s method of reporting data on drug application permits and denials is plausibly similar to the proposal in Loyola (2023) for the collection of uniform longitudinal data.

It is worth pointing out that the creation of FDA hedges themselves does not necessarily mean that an unquantifiable uncertainty became a quantifiable risk. As Jorring et. al. (2023) point out, the FDA hedge is best characterized as a financial innovation that enables risks to be shared more efficiently. The FDA hedge moved a risk that was uninsurable due to a lack of financial innovation into the insurable category. By contrast, due to the unpredictability of the process and the paucity of data, at least as it stands, by contrast, the constraint on the ability to hedge out energy infrastructure permitting risk in the U.S. is not, as it once was for FDA risk, a lack of financial innovation. It is the presence of Knightian uncertainty that would likely prevent a market for “infrastructure permitting hedges” from functioning even if financial instruments offered such a market. Hence, for now, reasonable goal for infrastructure permitting reform in the U.S. would be to create conditions such that a market for permitting hedges around energy infrastructure is within the realm of the feasible. Only then could financial innovation to create “permitting hedges” follow. When created, however such a market would encourage investment in infrastructure, much like FDA hedges are set to encourage pharmaceutical investment.

Finally, it is worth emphasizing that reforms that decrease the level of Knightian uncertainty do not necessarily leave environmental stakeholders worse-off. The removal of Knightian uncertainty from the permitting process would allow for the development of new energy infrastructure even if the odds of approval remained as low as environmental activists wanted. If any stakeholder would be worse-off from the removal of Knightian uncertainty in the U.S. energy infrastructure permitting process, it would be the firms whose profits from the possession of information about it. TAn example of such a firm may be Westney Consulting, a firm acquired by McKinsey in 2019 for its ability to benchmark the process of infrastructure projects, much of which a function of knowing the permitting process (McKinsey 2019). Those profits a are symptom, as Frank Knight laid out in 1921, of the presence of unquantifiable uncertainty and the economic value of any information that allows its mitigation. Those profits represent economic rents whose disappearance would offer little cause for lament.

**V. Conclusion**

Much about how Knightian uncertainty impacts economic activity in specific settings, like energy infrastructure, remains uncertain. This paper’s country-level index of insurability, interpretable as a measure of the absence of Knightian uncertainty, offers one contribution to try to advance that limited understanding. Based on correlations generated with that index, it does seem to be the case that Knightian uncertainty matters for country-level energy infrastructure outcomes, including the growth of renewable electricity. These results imply that reforming the infrastructure permitting process to mitigate or remove the Knightian uncertainty that it creates would, for those interested in developing U.S. energy infrastructure, be an evidence-based policy.

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**Table 1**

*Note: the units for insurance data are for non-life insurance premiums as a share of GDP, expressed as percentage points of GDP. For both ranks and raw data, lower values indicate less insurability and a greater presence of Knightian uncertainty.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Country | Rank, *R* | Rank, insurance data | Value, *R* | Value, insurance data |
| Egypt, Arab Rep | 1 | 5 | -1.22121 | 0.314473 |
| Bangladesh | 2 | 1 | -1.02343 | 0.172071 |
| Nigeria | 3 | 2 | -1.01669 | 0.196058 |
| Pakistan | 4 | 3 | -1.00171 | 0.211762 |
| Cambodia | 5 | 4 | -0.97759 | 0.269751 |
| Indonesia | 6 | 6 | -0.95521 | 0.434559 |
| Philippines | 7 | 8 | -0.93006 | 0.465697 |
| Kazakhstan | 8 | 11 | -0.80879 | 0.502152 |
| Vietnam | 9 | 17 | -0.74134 | 0.579654 |
| Tanzania | 10 | 9 | -0.69485 | 0.473716 |
| Saudi Arabia | 11 | 18 | -0.67691 | 0.672244 |
| Haiti | 12 | 13 | -0.67452 | 0.515749 |
| Georgia | 13 | 12 | -0.66777 | 0.507768 |
| Ghana | 14 | 10 | -0.6659 | 0.473846 |
| India | 15 | 15 | -0.6509 | 0.535737 |
| Sri Lanka | 16 | 16 | -0.6006 | 0.538075 |
| Cameroon | 17 | 14 | -0.54196 | 0.518807 |
| Moldova | 18 | 20 | -0.53973 | 0.721605 |
| Uganda | 19 | 7 | -0.49738 | 0.449499 |
| Algeria | 20 | 21 | -0.4356 | 0.725561 |
| Hungary | 21 | 34 | -0.43115 | 1.0836 |
| United Arab Emirates | 22 | 31 | -0.41788 | 1.05375 |
| Turkey | 23 | 28 | -0.40261 | 0.91038 |
| Guatemala | 24 | 19 | -0.39969 | 0.715611 |
| Bolivia | 25 | 22 | -0.36431 | 0.820116 |
| Russian Federation | 26 | 25 | -0.3481 | 0.86402 |
| China | 27 | 37 | -0.34221 | 1.15491 |
| Peru | 28 | 27 | -0.32236 | 0.886391 |
| Mexico | 29 | 24 | -0.25426 | 0.859165 |
| Romania | 30 | 29 | -0.2311 | 0.9474 |
| Botswana | 31 | 23 | -0.22406 | 0.851074 |
| Nicaragua | 32 | 33 | -0.21819 | 1.08084 |
| Jordan | 33 | 38 | -0.21048 | 1.22254 |
| Suriname | 34 | 35 | -0.20986 | 1.08909 |
| Lithuania | 35 | 30 | -0.20677 | 0.97854 |
| Brazil | 36 | 36 | -0.17163 | 1.09998 |
| Malawi | 37 | 26 | -0.16342 | 0.866125 |
| Thailand | 38 | 45 | -0.09948 | 1.31572 |
| Greece | 39 | 32 | -0.06066 | 1.05615 |
| Estonia | 40 | 42 | -0.04953 | 1.26267 |
| Ukraine | 41 | 40 | 0.01738 | 1.24875 |
| Colombia | 42 | 43 | 0.026201 | 1.28998 |
| Iran, Islamic Rep | 43 | 48 | 0.04449 | 1.41358 |
| Serbia | 44 | 41 | 0.052219 | 1.24957 |
| Poland | 45 | 44 | 0.097924 | 1.29782 |
| Croatia | 46 | 49 | 0.1467 | 1.4469 |
| Sweden | 47 | 51 | 0.147564 | 1.53525 |
| Kenya | 48 | 39 | 0.183111 | 1.24737 |
| Chile | 49 | 47 | 0.183317 | 1.39959 |
| Costa Rica | 50 | 46 | 0.197003 | 1.39186 |
| Netherlands | 51 | 55 | 0.241386 | 1.61766 |
| Bosnia and Herzegovina | 52 | 50 | 0.30733 | 1.49035 |
| Portugal | 53 | 57 | 0.33218 | 1.67035 |
| Italy | 54 | 53 | 0.356632 | 1.58866 |
| Rwanda | 55 | 52 | 0.364171 | 1.58527 |
| Morocco | 56 | 56 | 0.432073 | 1.65605 |
| Israel | 57 | 58 | 0.471861 | 1.69426 |
| Finland | 58 | 60 | 0.495404 | 1.8128 |
| Japan | 59 | 54 | 0.546286 | 1.60237 |
| Spain | 60 | 62 | 0.665568 | 2.03663 |
| Germany | 61 | 61 | 0.708097 | 1.91849 |
| Czech Republic | 62 | 59 | 0.718333 | 1.78505 |
| Switzerland | 63 | 63 | 0.761204 | 2.05904 |
| Australia | 64 | 66 | 0.829235 | 2.20879 |
| Austria | 65 | 65 | 0.878973 | 2.20762 |
| Argentina | 66 | 64 | 0.931814 | 2.09974 |
| United Kingdom | 67 | 68 | 1.016137 | 2.37302 |
| France | 68 | 67 | 1.025979 | 2.21556 |
| Canada | 69 | 70 | 1.305273 | 2.65923 |
| South Africa | 70 | 69 | 1.424596 | 2.5582 |
| United States | 71 | 71 | 1.845052 | 3.162 |
| Venezuela, RB | 72 | 72 | 2.260693 | 3.55511 |
| Korea, Rep | 73 | 73 | 3.456299 | 4.67482 |

1. That is based on the author’s conversation with one of its designers. [↑](#footnote-ref-1)