Innovation under Ambiguity and Risk

Gabriela Coiculescu (*Yeshiva*)
Yehuda Izhakian (*Baruch*)
S. Abraham Ravid (*Yeshiva*)

discussed by

Stephen J. Terry (*BU*)

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Two Types of Uncertainty

"...there are known unknowns...there are also unknown unknowns..."
- Donald Rumsfeld, 2002

Risk: uncertainty conditional upon probabilities

- With 40% prob., you get 0. With 60% prob., you get $1 million.
- Theories of *risk aversion* link risk to behavior.

Ambiguity: uncertainty about probabilities themselves

- With 40% prob., you get 0. With 60% prob., you get $1 million. Or, it might actually be 60/40. Who knows?
- Theories of *ambiguity aversion* link ambiguity to behavior.

Room for more work
It's fair to say that, both theoretically and empirically, ambiguity is understudied relative to risk. This nice paper makes progress in both directions.

Flexible Ambiguity Aversion

- Motivated by Izhakian (2017, 2020)'s EUUP theory
- Ambiguity-averse agents combine a distribution across ambiguous probabilities $\phi(x)$ into "perceived probabilities" $Q(x)$

$$Q(x) = \mathbb{E}\left[\phi(x)\right]\left(1 \pm \frac{\Upsilon''(1-\mathbb{E}\left[P(x)\right])}{\Upsilon'(1-\mathbb{E}\left[P(x)\right])} Var\left[\phi(x)\right]\right)$$

- Then, agents act based upon an objective with the perceived probabilities and standard expected utility $U(\cdot)$

$$\int U(x)Q(x)dx$$

- Good state $Q(x)$'s deflated, bad state $Q(x)$'s inflated, depending on the degree of ambiguity aversion in the function $\Upsilon(\cdot)$
- Much more flexible than traditional "max-min" approach.
- A natural measure of ambiguity is the probability-weighted variance of probabilities:

$$\mho^2 = \int \mathbb{E}\left[\phi(x)\right] Var(\phi(x))dx$$

A Natural Empirical Context: Risky Innovation

Not all R&D investments pay off with certainty.

A traditional risk-based approach has mixed implications:

- Risk is great! (anytime payoffs are convex)
- Risk is awful! (with certain adj. costs, fin. frictions, etc.)

But innovation might also involve ambiguity:

- Might be hard ex-ante to form a single precise distribution.
- Ambiguity aversion would robustly imply lower incentives to invest.

This paper's empirical approach and results
Firm regressions with Compustat + patent microdata + equity return-based proxies for risk and ambiguity reveal a negative association between ambiguity and R&D, patenting, with mixed results for risk.

So What's My View?

This is a really cool paper

- Nice motivation from a clean, flexible theory of ambiguity aversion which is less stark than usual
- Natural empirical focus on innovation, striking findings
- A lot to like in this project

Four things I want to know more about:

1. The assumptions justifying the empirical proxy for ambiguity
2. The potential impact of time-varying news and distributional shifts on the ambiguity measure
3. The potential for recently available survey data on uncertainty to aid in the measurement of ambiguity
4. R&D, endogenous distributional shifts, and causality

1: Another Day, Another Prior

The empirical proxy for ambiguity is computed as follows:

- Put all 5-minute equity returns for firm i in day d into a set of fixed return bins $j = 1, ..., n$ for all days d in month t.
- For firm i and month t and bin j, compute the mean and variance of the bin j-specific probabilities $P_{id}(j)$ across days d in t.

$$M_{it}(j) = \frac{1}{D} \sum_{d \in t} P_{id}(j), \quad V_{it}(j) = \frac{1}{D} \sum_{d \in t} \left(P_{id}(j) - M_{it}(j)\right)^2$$

- The ambiguity measure is proportional to the mean probability - weighted variance of the bin probabilities across days.

$$\hat{\mho}^2_{it} \propto \sum_{j=1} M_{it}(j) V_{it}(j)$$

Why assume each day is a different prior?
One could imagine that news which arrives within the month would shift the set of priors from which investors are drawing, leading to variance in bin probabilities even without ambiguity.

2: Distributional Shifts

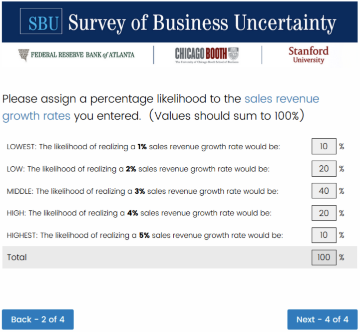
Consider, for concreteness, bad news for a firm which arrives two weeks into a given month and is known to investors.

Uncertainty lit. emphasizes three common distributional shifts
Often, we see some combination of the following three patterns in the firm data. First moments $\mathbb{E}\downarrow$, second moments $\sigma\uparrow$, and skewness $Skew\downarrow$.

	Ambiguity $\hat{\mho}$	Risk $\hat{\sigma}$
$\mathbb{E}\downarrow$	$\uparrow$	0
$\mathbb{E}\downarrow$, $\sigma\uparrow$	$\uparrow$	$\uparrow$
$\mathbb{E}\downarrow$, $Skew\downarrow$	$\uparrow$	0
$\mathbb{E}\downarrow$, $\sigma\uparrow$, $Skew\downarrow$	$\uparrow$	$\uparrow$

Pros and cons of the measure $\hat{\mho}$
Pro: picks up distributional shifts more robustly than the risk measure
Con: picks up distributional shifts in addition to ambiguity

3: Survey Data on Uncertainty



A new-ish representative monthly *Survey of Business Uncertainty* run by the Atlanta Fed asks for distributional forecasts separating probabilities and outcomes, allowing quite naturally for analysis of ambiguity vs risk. The microdata is available under agreement, and it's much easier to access than, e.g., Census microdata.

4: R&D and Endogeneity

The empirical specifications in the paper are some version of

$$X_{i,t+1} = \alpha + \beta\hat{\mho}_{it} + \gamma\hat{\sigma}_{it} + ... + \epsilon_{it}$$

for either R&D or patenting X in firm i at time t, and the word "effect" is used to describe the estimates $\hat{\beta}$, $\hat{\gamma}$ throughout the paper and abstract.

- This is likely a purely semantic point.
- But if R&D and innovation are risky, then changes in R&D can easily cause changes in perceived distributions (and hence ambiguity and risk measures), which would imply reverse causality.
- If projects pre-announced, timing doesn't eliminate the issue.
- So I'd switch to purely correlational language here.

An alternative approach
Look for an IV, perhaps with shift-share exposures at the industry level, to isolate externally induced changes in risk and ambiguity. See Stein & Stone (2013) for an example of this for risk with similar findings.

Takeaway

This is a really cool paper

- Clean theoretical motivation with a flexible notion of ambiguity
- Natural empirical context for the study of R&D, innovation, and uncertainty
- Skilled execution on both the theoretical and empirical fronts

My overall takeaway
The authors are well placed to shed light on my questions, as they continue what is already an excellent project!