Innovation under Risk and Ambiguity A research Proposal

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The purpose of the project is to investigate the effect of ambiguity on innovation. We provide a theoretical framework, and we are working on an extensive empirical analysis to test our views.

A large and growing body of literature investigates the determinants of innovation; such determinants include industry competition {Aghion etal., 2005}, institutional ownership {Aghion et al., 2013} and organizational structure {Lerner et al., 2011, Seru, 2014, Bernstein, 2015}.

Special attention has been given to uncertainty as a driver of innovative activity. Bloom (2007) and others investigate this channel. More recent work includes Bernstein et al. (2017} who suggest that economic risk (negative housing shocks) reduces employees' interest in risky and exploratory projects and Krieger and Papanikolaou (2017) who investigate the tradeoff between conservative and riskier investments in drug development.

Our paper contributes to this literature, by making the distinction between two aspects of uncertainty: risk and ambiguity (Knightian uncertainty). Risk is a condition where outcomes are a priori unknown, but the odds of all possible outcomes are perfectly known. Ambiguity is a condition where not only are outcomes a priori unknown, but also the odds of outcomes are unknown or not uniquely assigned.

Put differently, risk assumes a unique quantifiable distribution of future prospects. In reality, it may be very difficult to predict a distribution of outcomes for a new innovative product such as a new drug (Krieger and Papanikolaou 2017).

Therefore, the concept of ambiguity---the uncertainty of probabilities---seem a natural lens through which managers may view future prospects.

We follow Schwartz (2004) and consider patent and R&D decisions as real options. However, whereas in Schwartz (2004) the value of these real options is subject to risk only, we show that the value of real options should be also significantly affected by ambiguity. (following Izhakian and Yermack, 2017, Augustin and Izhakian, 2016).

Our theoretical framework thus values real options when the decision maker is ambiguity averse and either risk averse or risk neutral.

The main hypotheses derived from this model are that while risk has a positive effect on investment decisions, ambiguity has a negative effect on investment.

The intuition is that higher risk is associated with a higher value of the real option, which encourages investment. In contrast, since higher ambiguity leads decision makers to overweight the

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likelihoods of bad outcomes and underweight the likelihoods of good outcomes, it will reduce innovative activity.

Empirically, we map this framework to investments and R&D and patenting.

Data and Methodology

The primary data sources for this research project are: the National Bureau of Economic Research (NBER) patent database and the Harvard Business School (HBS) Patent Database, for historical information on patents, the intraday Trade and Quote (TAQ) data for the estimation of the firm-specific degree of ambiguity, the Chicago Center for Research in Security Prices (CRSP) database for the estimation of firm risk, and Compustat for accounting data.

To proxy for the ambiguity associated with a firm, we estimate the ambiguity of its equity. We employ the empirical method used by Izhakian and Yermack (2017) to estimate the degree of ambiguity using intraday stock trading data from the TAQ database. In this approach, we suppose the existence of a representative agent with a set of priors over the intraday return distributions. The observed intraday returns on the underlying asset are assumed to be a realization of one specific prior. That is, every day is characterized by a different distribution of returns, and the set of these distributions over a month represents the agent's set of priors. After we divide the range of daily returns into 160 intervals (bins), we calculate for each interval the variance over the month of the probability of the return being in that interval. Our empirical proxy for the monthly ambiguity of a stock is the average of these variances across all return intervals.

This research project will examine several measures of innovation, including both investment in innovation (R&D investment, scaled by either sales, assets or assets adjusted to include capitalized investment in R&D and other intangible assets) and innovation intermediate output (patents, citations-weighted patents, patent originality and generality, as well as the propensity to exploit the firm's existing knowledge versus exploring new knowledge). It will adopt a variety of modern econometric techniques, including linear panel data models to analyze R&D investment and count models that account for firm heterogeneity and excess zeroes, such as zero-inflated and hurdle models for patents and citations.

Preliminary runs seem to support our theoretical view that when significant, risk increases R&D investment and patenting activity, and ambiguity decreases both. However, it seems that small and young firms, early in their life cycle "care" more about ambiguity whereas it is the more established firms for whom risk matters most.

We have run a few robustness checks and we plan to expand the analysis.

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Budget estimate:

The budget is to be divided among the three authors, two junior researchers and a senior researcher.

Project expenses

Research assistance $ 2000

Data purchase and analysis $5000

Travel for project related conferences and discussions with industry professionals

$4000 for each of the three researchers, $12,000.

Total $19,000.