

Entrepreneurs as Scientists, Bayesian Inference, and Belief Revision

Thomas Zellweger, University of St. Gallen

Todd Zenger, University of Utah

Forthcoming in *Journal of Business Venturing Insights*

We are delighted to see active conversation and debate (see also Sergeeva, Bhardwaj, & Dimov, 2022) around our paper “Entrepreneurs as Scientists: A pragmatist approach to producing value under uncertainty”, forthcoming in the *Academy of Management Review* (Zellweger & Zenger, 2022b).¹ In a thoughtful and provocative comment published in *Journal of Business Venturing Insights*, Ehrig and Foss (2022), while embracing the emerging idea of entrepreneurs as scientists who compose and test theories (Camuffo, Cordova, Gambardella, & Spina, 2020; Ehrig & Schmidt, 2022; Felin & Zenger, 2009), offer two important critiques focused on our use of Bayesian logic and language. First, they argue that Bayesian learning fails in the presence of Knightian uncertainty or the unknown unknowns that are commonplace in entrepreneurial settings. In a nutshell, they argue that the entrepreneurial process is frequently filled with what Simon characterized as ‘surprises’ (Simon, 1989) or the arrival of data or states that are outside any composition of subjective probabilities, and therefore cannot be a basis for Bayesian updating. Second, they argue that (p. 3) “entrepreneurial theories (in the sense of Felin & Zenger, 2017) contain systems of conditional belief or assumptions” that again cannot be tested and subjected to Bayesian updating as a whole, though they acknowledge that individual assumptions

¹ We would like to thank Dimo Dimov and Timo Ehrig for their comments on earlier versions of this commentary.

or subsets of assumptions, may be testable through Bayesian inference. As their title, “Why we need normative theories of entrepreneurial learning that go beyond Bayesianism,” aptly summarizes, their message is that a normative theory in which entrepreneurs are encouraged to act like scientists needs a model of learning that goes beyond Bayesianism or at least an augmented or qualified version of Bayesianism—one that allows unsupported beliefs or priors to be discarded and replaced.

We actually strongly agree and argue that precisely this form of augmented Bayesianism is what defines a pragmatist entrepreneur—an entrepreneur who acts like a scientist. In the reply that follows, we respond to the Ehrig-Foss critique. Rather than quibble about minor wording issues around uncertainty—ontological differences that we deem of lesser significance to pragmatism and which we have addressed elsewhere (Zellweger & Zenger, 2022a), we focus on furthering the shared agenda of illuminating this augmented Bayesian logic that we both see as foundational.

We address each of their two critiques. First, we argue that the form of entrepreneurial learning we have described and advocated for is not strictly Bayesian in the sense that through learning the entrepreneur is “‘getting closer’ to an existing reality” (Ehrig & Foss, 2022, p. 2). Rather we advocate for a form of “scientific entrepreneurship”—a form of learning that is enabled by well-structured theories as priors, facilitated by theory-guided testing and data interpretation, followed by theory updating or complete theory abandonment based on feedback. When scientific entrepreneurship reveals surprising feedback (perhaps derived from unknown unknowns)—a recognition only possible precisely because entrepreneurs possess a theory that defines what is inconsistent or surprising (Kulkarni & Simon, 1988), entrepreneurs must then revise their problem formulations, and update or abandon their theories. For pragmatists, theories are retained and abandoned based on whether they “work” and the “truth [of a theory] is simply a compliment paid to sentences seen to be paying their way” (Rorty, 1982; p. 13). We see this form of pragmatist scientific entrepreneurship, where theories are empirically tested but also

routinely revised and replaced, as in line with the augmented or qualified form of Bayesianism that Ehrig and Foss see as a path forward.

Second, consistent with Ehrig and Foss, we reiterate our argument from Zellweger and Zenger (2022b) that the virtue of testing a well-structured theory is that this permits Bayesian-type learning about specific assumptions and sub-beliefs. In other words, Bayesian learning is not only derived from observing feedback to a theory fully composed with a complete product or business model, but more importantly occurs as assumptions are tested and subproblems explored. Finally, we conclude by pointing to opportunities to further clarify our scientific approach to entrepreneurship.

How does a scientific entrepreneur respond to surprise?

We should state at the outset that our agenda is to advance the idea that founders are ideally pragmatists who behave like scientists in search of value. They should begin with theories of value that are analogous to what Bayesians call priors, but these theories should be formulated around a problem, framed with conceptually coherent assumptions and causal logic (Murphy & Medin, 1985). Seeing priors as theories, more specifically as theories of value creation (Felin & Zenger, 2017), represents a useful abstraction that guides reasoning and action under uncertainty (Ehrig & Schmidt, 2022). In contrast to frequentist approaches that seek to assess the probability of data, Bayes focuses on the probability of a theory, given the data. Following Ramsey (1926/2016) we see entrepreneurial theories as representational artifacts that indicate degrees of belief with assigned subjective probabilities and willingness to bet and act upon them (Hájek & Staffel, 2021). To increase the odds of creating value under such uncertain circumstances, the scientific method suggests making theories explicit and then testing them, often by testing the assumption that the entrepreneur deems most improbable (Ehrig & Schmidt, 2022), or the assumption deemed most entrenched, i.e. critical, for the idea to work (Gärdenfors, 2003).

In their effort to create value, entrepreneurial scientists begin from the known. They begin from an observed problem from which they compose a theory with accompanying assumptions

and logic—a theory that is of unknown value in generating an effective solution. For pragmatists, valuable theories are those that “[pay] their way” (Rorty, 1982; p. 13)—that lead to solutions that are valued in the market.² These theories identify assumptions to test, experiments to run, data to gather, and provide the backdrop against which unknown surprises are recognized.

Of course, with complex, uncertain environments, entrepreneurs frequently observe surprises or unexpected states that call into question particular assumptions and their corresponding theories (Simon, 1989). Ehrig and Foss (2022; p. 2) fear that “using Bayes’ rule to update entrepreneurial theories will almost certainly lead to failure” since “Bayesian learning does not have a mechanism to cope with including new states”. Here is where classical Bayesian inference requires augmentation—entrepreneurs must either revise their theories to accommodate these surprises, or abandon them altogether in favor of an alternative. After all, for most entrepreneurs, the outcome of Bayesian inference is an unsupported assumption and/or invalidated theory, and the faster such conclusions are reached the less costly the outcome is for the entrepreneur (Amore, Garofalo, & Martin-Sanchez, 2021; Stevenson, Allen, & Wang, 2022). Early learning, often from early surprises, yields a newer theory sooner—one that more likely yields a product of value in the market. In other words, when the posterior probability of the original idea proves to be low, often zero, the information gleaned in a first cycle of scientific inquiry, particularly surprises, may inspire a new theory, i.e. a next prior, that was unimaginable to the entrepreneur before the process started.

Toward the end of his life, Herbert Simon composed a wonderful essay reflecting on his own learning process as a scientist. His observation was that many of his earliest and most profound theoretical insights as a scholar came from observations that were identifiable as

² The idea that the market, more specifically the client, is the ultimate judge about the value of an idea resonates with von Mises (1966/2016; p. 270) who states: «The direction of all economic affairs is in the market society a task of the entrepreneurs. Theirs is the control of production. They are at the helm and steer the ship. A superficial observer would believe that they are supreme. But they are not. They are bound to obey unconditionally the captain’s orders. The captain is the consumer.»

surprising precisely because they were inconsistent with priors he had developed from the economic theories of his training (Simon, 1989). Simon (1989) suggests that (p. 22):

“One good reason for running an experiment or for spending one’s time just observing phenomena closely is that you may be surprised. The best things that come out of experiments are things that we did not expect to come out—especially those that we couldn’t even have imagined in advance as possibilities.”³

But the presence of a structured prior is what allows scientific entrepreneurs to reach a conclusion that what they just observed is aligned with, violates, or falls outside their theories. As Kulkarni and Simon (1988; p. 151) note: “If the outcome of an experiment violates the expectations for it, then make the study of this puzzling phenomenon a task and add it to the agenda.” In other words, update the theory or compose a new one based on this new and expanded problem formulation, and then return to testing and Bayesian learning. In sum, multiple rounds of sequentially deployed Bayesian inference become the mechanism to cope with new states. By cycling between theorizing and testing, while both corroborating assumptions and incorporating surprises, entrepreneurs refine their theories toward those with higher probability of success.

We agree with Ehrig and Foss (2022) that more research is needed not only on how Bayesianism is used to inform and update priors, but also on processes beyond classic Bayesianism that tell entrepreneurs when and how they should abandon, revise, and update their beliefs. In this sense, future research may study what happens “in-between” Bayesian learning cycles⁴, where Bayesian rationality and theories of belief revision may combine to provide a fruitful way forward. For instance, it seems worthwhile to study effective heuristics for this process of theory updating, including the process of deciding what stays and what goes, as

³ Simon (1989) proceeds with suggesting that (p. 31): «Perhaps it is not our methodology that needs revising so much as the standard textbook methodology which perversely warns us against running an experiment until precise hypotheses have been formulated and experimental and control conditions defined. How do such experiments ever create surprise—not just the all-too-common surprise of having our hypotheses refuted by facts, but the delight-provoking surprise of encountering a wholly unexpected phenomenon.»

⁴ We wish to thank Timo Ehrig for a related comment.

entrepreneurs receive feedback that challenges their beliefs (Alchourrón, Gärdenfors, & Makinson, 1985; Rott, 2021).

Our approach to combining Bayesian inference and belief revision is to explore more deeply the pragmatist processes by which scientific entrepreneurs determine which theories are paying their way and which are not (Quine, 1951). We also recognize that because beliefs are self-populated by the entrepreneur, that they are highly sensitive to bias, reflecting the entrepreneur's unique experiences and observation before starting the venture. Hence, the degree of informedness of the prior held by the entrepreneur, in particular about the prior's desirability, feasibility and economic viability (Barreto & Patient, 2013; Dimov, 2016; McMullen & Shepherd, 2006), should critically determine the prior's error, and by implication, the business idea's fit to the market (Geman, Bienenstock, & Doursat, 1992; Satopää, Salikhov, Tetlock, & Mellers, 2021; Zyphur & Oswald, 2015). In light of the subjective, personalized nature of theories, scientific entrepreneurs thus need to stay alert to surprises that arise as they engage in testing their theories, as these surprises and the updated theories that ensue are vital to elevating product market fit (Gilboa & Marinacci, 2016).

On the capacity of testing entrepreneurial theories as a whole

In their second critique, Ehrig and Foss (2022) propose that entrepreneurial theories contain systems of conditional belief or assumptions that cannot be tested and subjected to Bayesian updating as a whole, though Ehrig and Foss acknowledge that individual assumptions or subsets of assumptions may be testable through Bayesian inference. We agree in the sense that there is variance in the extent to which business ideas are amenable to testing. For instance, while a minimum viable product may be useful to test business ideas that require little upfront investment, or for which a key feature can be readily made available for testing, this test heuristic should be of limited value in testing ideas that require heavy upfront investments to present key features, such as constructing a production facility or composing complementary products. But even in this case, as discussed in Zellweger and Zenger (2022b), core assumptions can be

explored by evaluating analogous offerings, or by staging investments consistent with the belief. Despite such variance in the amenability of business ideas to testing, sooner or later, solutions derived from theories need to be put to a test in the market. Here, the challenge for the entrepreneur is to identify tests that are cheap yet also informative in their capacity to detect the true value of the entrepreneur's theory by reducing noise in the data (Agrawal, Gans, & Stern, 2021). This raises important questions about the optimal sequence of tests (Weitzman, 1979) and, more generally, the efficient extraction of valid information from the environment (Satopää et al., 2021).

In the fuzzy frontend of the entrepreneurial process the scientific approach to entrepreneurship helps the entrepreneur separate valuable from invaluable beliefs, and pursue a path more pragmatically useful than following gut feelings and intuition (Baldacchino, Ucbasaran, Cabantous, & Lockett, 2015; Huang & Pearce, 2015; Mitchell, Friga, & Mitchell, 2005). Of course, we recognize wide variance in the degree to which entrepreneurs adopt and skillfully deploy the steps inherent to this pragmatic, scientific and at times Bayesian learning process (Hunt, Lerner, Johnson, Badal, & Freeman, 2022). We thus refrain from suggesting that the scientific method is the only way to create value in entrepreneurship. But the agenda we share with Ehrig and Foss is normative—to elevate and accelerate entrepreneurs' capacity to create value. The logical predictions of pursuing more “scientific entrepreneurship” are that scientific entrepreneurs, in comparison to those who adopt a more intuitive, gut-feeling approach, will (1) more quickly terminate projects as they recognize that many ideas are not worthy of pursuit, (2) more quickly pivot as they learn faster about the value of an idea, (3) perhaps pivot fewer times as they undertake informative tests that scrutinize core assumptions underlying the idea, and finally (4) pursue more valuable ideas as they are less likely to form and settle on beliefs with little product-market fit. By providing structured guidance to testing, pivots, and belief revision, we view scientific entrepreneurship as a process that is leaner than lean startup.

Conclusion

We recognize that the entrepreneurial process is often filled with surprises (Simon, 1989) or the arrival of information that lays outside the entrepreneur's priors, which challenges classical Bayesian inference and its formal closure. Scientific entrepreneurship requires a version of or an addition to Bayesianism in which unsupported priors can be revised, discarded and replaced. Further exploring the linkages between entrepreneurship, Bayesianism and theories of belief revision promise to render the entrepreneurial process more accessible to formal economic modeling, which should help augment the micro-foundations of entrepreneurial action (Grenadier & Malenko, 2010; Kerr, Nanda, & Rhodes-Kropf, 2014; Manso, 2011, 2016; Parker, 2018). What is missing to date is an engagement with Bayesian inference as a way to wholistically model entrepreneurial action (cf. Camuffo, Gambardella, Maccheroni, Marinacci, & Pignataro, 2022; Denrell & Fang, 2010; Kapoor & Wilde, 2022; Lohrke, Carson, & Lockamy, 2018; McCann, 2020), and we hope that our scientific perspective of entrepreneurship will be useful in related endeavors.

We conclude by stressing that the core theoretical foundation we adopt in our scientific perspective of entrepreneurship is pragmatism. This entails that entrepreneurship starts with abduction (see also Sætre & Van de Ven, 2021), suggesting that an idea *may* be, followed by deduction, suggesting what then *must* be, followed by induction, finding out whether the idea *is actually* operative (Peirce, 1992). Of course, getting to something *actually* operative may demand multiple cycles through this process as beliefs are revised. Ultimately, our aim is not to determine whether entrepreneurs are or are not strict Bayesians, but rather to provide a pragmatic theory—a theory for use—one that elevates the value creating capacity of entrepreneurs.

References

- Agrawal, A., Gans, J. S., & Stern, S. 2021. Enabling entrepreneurial choice. *Management Science*, 67(9): 5301-5967.
- Alchourrón, C. E., Gärdenfors, P., & Makinson, D. 1985. On the logic of theory change: Partial meet contraction and revision functions. *Journal of Symbolic Logic*, 50(2): 510-530.
- Amore, M. D., Garofalo, O., & Martin-Sanchez, V. 2021. Failing to learn from failure: How optimism impedes entrepreneurial innovation. *Organization Science*, 32(4): 940-964.
- Baldacchino, L., Ucbasaran, D., Cabantous, L., & Lockett, A. 2015. Entrepreneurship research on intuition: A critical analysis and research agenda. *International Journal of Management Reviews*, 17(2): 212-231.
- Barreto, I., & Patient, D. L. 2013. Toward a theory of intraorganizational attention based on desirability and feasibility factors. *Strategic Management Journal*, 34(6): 687-703.
- Camuffo, A., Cordova, A., Gambardella, A., & Spina, C. 2020. A scientific approach to entrepreneurial decision making: Evidence from a randomized control trial. *Management Science*, 66(2): 564-586.
- Camuffo, A., Gambardella, A., Maccheroni, F., Marinacci, M., & Pignataro, A. 2022. Microfoundations of Low-Frequency High-Impact Decisions. *Bocconi University Working Paper*.
- Denrell, J., & Fang, C. 2010. Predicting the next big thing: Success as a signal of poor judgment. *Management Science*, 56(10): 1653-1667.
- Dimov, D. 2016. Toward a design science of entrepreneurship. In A. C. Corbett, & J. A. Katz (Eds.), *Models of start-up thinking and action: Theoretical, empirical and pedagogical approaches*, Vol. 18: 1-31. London: Emerald Group Publishing.
- Ehrig, T., & Foss, N. J. 2022. Why we need normative theories of entrepreneurial learning that go beyond Bayesianism. *Journal of Business Venturing Insights*: forthcoming.
- Ehrig, T., & Schmidt, J. 2022. Theory-based learning and experimentation: How strategists can systematically generate knowledge at the edge between the known and the unknown. *Strategic Management Journal*, forthcoming.
- Felin, T., & Zenger, T. R. 2009. Entrepreneurs as theorists: on the origins of collective beliefs and novel strategies. *Strategic Entrepreneurship Journal*, 3(2): 127-146.
- Felin, T., & Zenger, T. R. 2017. The theory-based view: Economic actors as theorists. *Strategy Science*, 2(4): 258-271.
- Gärdenfors, P. 2003. *Belief revision*. Cambridge: Cambridge University Press.
- Geman, S., Bienenstock, E., & Doursat, R. 1992. Neural networks and the bias/variance dilemma. *Neural Computation*, 4(1): 1-58.
- Gilboa, I., & Marinacci, M. 2016. Ambiguity and the Bayesian paradigm. In H. Arló-Costa, V. Hendricks, & J. van Benthem (Eds.), *Readings in Formal Epistemology*, Vol. 1: 385-439. Cham: Springer.
- Grenadier, S. R., & Malenko, A. 2010. A Bayesian approach to real options: The case of distinguishing between temporary and permanent shocks. *Journal of Finance*, 65(5): 1949-1986.
- Hájek, A., & Staffel, J. 2021. Subjective Probability and Its Dynamics. In M. Knauff, & W. Spohn (Eds.), *The Handbook of Rationality*: 239-252. Cambridge, MA: MIT Press.
- Huang, L., & Pearce, J. L. 2015. Managing the unknowable: The effectiveness of early-stage investor gut feel in entrepreneurial investment decisions. *Administrative Science Quarterly*, 60(4): 634-670.
- Hunt, R. A., Lerner, D. A., Johnson, S. L., Badal, S., & Freeman, M. A. 2022. Cracks in the wall: Entrepreneurial action theory and the weakening presumption of intended rationality. *Journal of Business Venturing*, 37(3): 106190.
- Kapoor, R., & Wilde, D. 2022. Peering into a crystal ball: Forecasting behavior and industry foresight. *Strategic Management Journal*, forthcoming.

- Kerr, W. R., Nanda, R., & Rhodes-Kropf, M. 2014. Entrepreneurship as experimentation. *Journal of Economic Perspectives*, 28(3): 25-48.
- Kulkarni, D., & Simon, H. A. 1988. The processes of scientific discovery: The strategy of experimentation. *Cognitive Science*, 12(2): 139-175.
- Lohrke, F. T., Carson, C. M., & Lockamy, A. 2018. Bayesian analysis in entrepreneurship decision-making research. *Management Decision*, 56(5): 972-986.
- Manso, G. 2011. Motivating innovation. *Journal of Finance*, 66(5): 1823-1860.
- Manso, G. 2016. Experimentation and the Returns to Entrepreneurship. *Review of Financial Studies*, 29(9): 2319-2340.
- McCann, B. T. 2020. Using Bayesian updating to improve decisions under uncertainty. *California Management Review*, 63(1): 26-40.
- McMullen, J. S., & Shepherd, D. A. 2006. Entrepreneurial action and the role of uncertainty in the theory of the entrepreneur. *Academy of Management Review*, 31(1): 132-152.
- Mitchell, J. R., Friga, P. N., & Mitchell, R. K. 2005. Untangling the Intuition Mess: Intuition as a Construct in Entrepreneurship Research. *Entrepreneurship: Theory & Practice*, 29(6): 653-679.
- Murphy, G. L., & Medin, D. L. 1985. The role of theories in conceptual coherence. *Psychological Review*, 92(3): 289.
- Parker, S. C. 2018. *The economics of entrepreneurship*. Cambridge: Cambridge University Press.
- Peirce, C. S. 1992. *The essential Peirce: selected philosophical writings*. Bloomington: Indiana University Press.
- Quine, W. v. O. 1951. Two dogmas of empiricism. *The Philosophical Review*, 60(1): 20-43.
- Ramsey, F. P. 1926/2016. Truth and probability. In H. Arló-Costa, V. F. Hendricks, & J. van Benthem (Eds.), *Readings in formal epistemology*. 21-45. Cham: Springer.
- Rorty, R. 1982. *Consequences of pragmatism: Essays, 1972-1980*. Minneapolis: University of Minnesota Press.
- Rott, H. 2021. Belief Revision. In M. Knauff, & W. Spohn (Eds.), *The Handbook of Rationality*. 327-336. Cambridge, MA: MIT Press.
- Sætre, A. S., & Van de Ven, A. 2021. Generating theory by abduction. *Academy of Management Review*, 46(4): 684-701.
- Satopää, V. A., Salikhov, M., Tetlock, P. E., & Mellers, B. 2021. Bias, information, noise: The BIN model of forecasting. *Management Science*, 67(12): 7599-7618.
- Sergeeva, A., Bhardwaj, A., & Dimov, D. 2022. Mutable reality and unknowable future: Revealing the broader potential of pragmatism. *Academy of Management Review*, forthcoming.
- Simon, H. A. 1989. The scientist as problem solver. In D. Klahr, & K. Kotovsky (Eds.), *Complex information processing: The impact of Herbert A. Simon*. 375-398. Hillsdale, NJ: Erlbaum.
- Stevenson, R., Allen, J., & Wang, T. 2022. Failed but validated? The effect of market validation on persistence and performance after a crowdfunding failure. *Journal of Business Venturing*, 37(2): <https://doi.org/10.1016/j.jbusvent.2021.106175>.
- Von Mises, L. 1966/2016. *Human action*. Morrisville: Lulu Press, Inc.
- Weitzman, M. 1979. Optimal Search for the Best Alternative. *Econometrica*, 47(3): 641-654.
- Zellweger, T. M., & Zenger, T. R. 2022a. Entrepreneurs as Scientists: A pragmatist alternative to the creation-discovery debate. *Academy of Management Review*, forthcoming.
- Zellweger, T. M., & Zenger, T. R. 2022b. Entrepreneurs as Scientists: A pragmatist approach to producing value out of uncertainty. *Academy of Management Review*, forthcoming.
- Zyphur, M. J., & Oswald, F. L. 2015. Bayesian estimation and inference: A user's guide. *Journal of Management*, 41(2): 390-420.