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Diversity in Economics: an Evolutionary Game Theoretic Perspective

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1 Introduction

The field of economics has long been criticized for its lack of diversity, particularly with regard to the underrepresentation of women. While the problem of diversity is not unique to economics, the persistence of gender inequality in the field raises important questions about the epistemological and methodological assumptions that underpin economic theory and research. During the period spanning from 2013 to 2016, the representation of female economists in terms of authorship of papers published for the National Bureau of Economic Research (NBER) amounted to a mere 20.6 percent (Chari & Goldsmith-Pinkham, 2018). Moreover, women's share of contributions to the Papers and Proceedings by the American Economic Association averaged only 26.4 percent in 2011–20, remaining even below women's 33% share of new PhDs in economics (Meade, Starr, & Bansak, 2021).

The underrepresentation of women in economics has been attributed to a number of factors, including gender biases in hiring and promotion, the lack of female role models in the field, and the persistence of traditional gender norms and stereotypes (Sarsons, 2017; Lundberg & Stearns, 2019; Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012). These factors seem to perpetuate the existing gap and slow down the turnaround toward a more balanced representation in the field. While the reasons at the root of this discrimination are mostly agreed upon by the literature, it has not been yet determined what the repercussions of this imbalance entail. Not only from an economic standpoint, but also from a philosophical perspective, what are the effects of lacking diversity in economics? Is diversity methodologically and epistemologically desirable?

In fact, there exist deep epistemological and methodological assumptions about what counts as legitimate economic knowledge. The lack of diversity in economics raises important questions about the validity and generalizability of economic theories and models given the importance of assumptions in economics. The underrepresentation of women may result in a narrower range of research questions and methodologies, leading to a biased and incomplete understanding of economic phenomena. By excluding diverse perspectives and experiences, economics may be limiting its ability to generate accurate and reliable knowledge about the world.

For example, feminist economists have argued that the dominant economic paradigm, which emphasizes individual rationality and market efficiency, is itself gendered, reflecting a masculine worldview that overlooks the social and environmental costs of economic activity (Nelson, 1996). By excluding alternative perspectives and ways of knowing, economics may be perpetuating a narrow and exclusionary approach to economic inquiry that limits its ability to address real-world problems and challenges. There is (feminist) literature that shares this idea that economic thinking should undergo a radical change to endorse a broader conception of the human identity and abandon those assumptions that are rooted in neo-classical economics. This is a view that has been discussed at length and advocates for a paradigmatic shift in economic science. From here on, however, it will be argued that some of the points of critique from this strand of the literature are very relevant in neo-classical economics as well. In fact, assuming that economics is value-laden, I argue that an account of strong objectivity and more diversity are methodologically and epistemologically desirable even in "mainstream" economics in its current state of the art. Moreover, by means of a series of evolutionary game theoretic simulations, I attempt to reveal the "epistemic potential" of a more diverse research community. In fact, if microeconomics is the most significant subfield in economics (as recent developments seem to suggest), then a larger share of female economists can help achieve better epistemic progress and epistemic quality.

The thesis proceeds as follows. Section 2 discusses the possibility of adopting a strong objectivity account in mainstream economics. Section 3 describes the evolutionary game theoretic simulations, especially in relation to the existing literature, and discusses the results of the simulation. Section 4 addresses the limitations of the simulations, and suggests some improvements for future models. Finally, section 5 concludes.

2 Strong objectivity

2.1 Feminist Economics

Nelson (1996) is one of the first and most important critiques of mainstream economics from a feminist perspective. In her book, Nelson argues that the dominant economic paradigm is not only ideologically biased towards a narrow conception of rationality, but also perpetuates gendered assumptions and stereotypes that limit its ability to generate accurate and reliable economic knowledge.

One of the main criticisms that Nelson levels against mainstream economics is its emphasis on individual rationality as the basis for economic behavior. According to Nelson, this assumption reflects a narrow and exclusionary approach to economic inquiry that overlooks the social and environmental costs of economic activity. By ignoring the broader social and environmental contexts in which economic decisions are made, mainstream economics may be perpetuating a view of economic activity that is incomplete and also harmful to the well-being of individuals and communities.

Another important criticism that Nelson makes is that mainstream economics is often characterized by a lack of diversity and inclusivity. Women and other marginalized groups are often excluded from economic decision-making processes and from the development of economic theories and models. This exclusionary approach to economic inquiry not only perpetuates gendered assumptions and stereotypes, but also limits the ability of economics to generate accurate and reliable knowledge about the world.

Moreover, Nelson argues that mainstream economics often relies on a view of objectivity that is itself gendered and exclusionary. According to Nelson, the idea of objectivity in economics is often defined in terms of detached, dispassionate analysis that is divorced from the social and political context. This view of objectivity overlooks the ways in which gendered assumptions and stereotypes shape economic inquiry, and perpetuates the narrow and exclusionary approach to economic knowledge that she describes.

Overall, feminist economics advocated for the creation of a more diverse and inclusive research environment, and challenges the dominant economic paradigm to be more open to alternative perspectives and ways of knowing (epistemes). This revolution would change the economic science as it is intended today. Can economics still retain some of its core assumptions while being more inclusive? I argue that such a radical switch is not necessary, yet, even in the current economic paradigm, diversity can be desirable and foster positive developments, as long as we assume that economics is not value-free.

2.2 Value-free or value-laden economics?

One of the most long-standing and (possibly) unresolved debates in economics concerns whether economic science is value-free or whether it is impregnated with values.

> Economics deals with ascertainable facts; ethics with valuations and obligations. The two fields of inquiry are not on the same plane of discourse.

Ever since Robbins (1932) famously wrote this quote, arguments on the value-ladeness vs. value-freedom of economics have been infuriating on both sides of the debate.

Friedman (1966) wrote a seminal work in this debate, strongly advocating for the ability of economics at restraining from normative judgments and moral consideration. He argued that economics should be studied as a positive science, in which theories are developed and tested through empirical observation and analysis. According to Friedman, this approach to economics provides a rigorous and scientific framework for understanding economic phenomena and making policy decisions. In fact, Friedman distinguished between positive and normative statements in economics. Positive statements are statements that can be tested against empirical evidence, while normative statements are statements that express value judgments or opinions. Friedman argues that economics should be concerned with the former, and that normative statements should be left to individual judgment and opinion. One of the key contributions of Friedman is his argument that economic models should be judged not by their realism, but by their predictive power. In fact, Friedman suggests that the validity of an economic theory should be judged on the basis of its ability to generate accurate predictions about economic outcomes, rather than on its conformity with theoretical or philosophical principles. Friedman claimed that economic models should be constructed with the goal of making accurate predictions about economic outcomes, rather than with the goal of accurately reflecting the underlying mechanisms of economic phenomena. Therefore, the predictive power of an economic model is the primary (and possibly only) criterion by which it should be judged.

While Friedman's view was mostly widespread for the majority of the twentieth century, in the new millennium a new trend questioning the value-freedom of economics emerged and started attracting ever more supporters. First, Atkinson (2009) argued that economics should be considered a moral science, and ethical considerations are crucial in economic analysis and policymaking. Welfare judgments are subjective and depend on the criteria applied. Different theories of justice can lead to different conclusions about the welfare consequences of economic changes or policy proposals. Atkinson stresses the need to recognize and engage with these different perspectives, rather than assuming a general consensus or ignoring welfare judgments altogether. More recently, Reiss (2017) tried to dismantle Friedman's argument step by step, showing several instances where modern economics is impregnated with values. In fact, Reiss claims that the distinction between "positive" and "normative" economics is not always clear-cut and that there is often a degree of "fact-value entanglement" in economic research.

Reiss refers to Friedman's perspective and identifies it as advocating the fact-value separability thesis. This thesis posits two main claims: (1) factual statements are true based solely on the nature of the world, independent of non-epistemic value judgments, and (2) the truth of factual statements can be determined without relying on non-epistemic value judgments. The second claim implies that factual statements and value judgments have distinct methods of verification or proof. Thus, Friedman maintains that factual statements can be understood independently of non-epistemic value judgments. Therefore, due to this distinction between facts and values, scientific inquiry should focus on epistemic values and refrain from incorporating non-epistemic values. However, this distinction is often not unequivocal because many economic theories and policy recommendations involve both value judgments and factual claims. An example is cost-benefit analysis, which is commonly used to evaluate the desirability of policy proposals, and combines both factual and value judgments.

More interestingly, Reiss (2017) also contends that positive economists often make value judgments without acknowledging them, which can lead to confusion and bias in economic research. He also argues that even when economists try to separate positive and normative economics, the two are often intertwined. For instance, take the case of the unemployment rate, which, at first sight, seems to be an objective and value-free measure. The unemployment rate is defined as the ratio of currently unemployed individuals to the total size of the labor force. Someone is regarded as unemployed when they are not working, but are currently available to work and actively seeking a job. However, what does it mean to be actively looking for a job? The answer involves value judgments about the level of effort or commitment required to be considered active. Determining which activities are considered active job search efforts and which are not can reflect societal values, cultural norms, or policy priorities. These judgments can be influenced by how important one deems individual initiative, the role of the government in facilitating employment, or the expectations placed on job seekers. Else, consider the fact that children below 16 years old are not included in this count. This inherently implies a moral judgment about the wrongness and impropriety of child labor. Most societies and international conventions consider child labor morally unacceptable due to concerns regarding the well-being, rights, and development of children, which is reflected in this choice.

In particular, Reiss identifies five domains where value judgments enter the economic sphere.

Firstly, he argues that rational choice theory is inherently value-laden because rational-choice theory imposes, possibly involuntarily, a standard of rationality. Economists claim the assumptions for the *homo economicus* are merely positive, they do not tell people what to prefer as long as their preferences follow these "rational" assumptions. However, by labeling this decision-making process as "rational," the theory implicitly sets a normative standard of how individuals ought to make choices. It implies that deviations from this standard are irrational or suboptimal, implying a normative judgment. Naming a certain decision-making process "rational choice" suggests setting certain practices as a standard to be met.

Secondly, Reiss suggests that concept formation is also value-laden because it involves defining and categorizing economic phenomena. Different concepts and categories may reflect different values and interests, and therefore cannot be considered purely factual. Take the previous example of the unemployment rate, or think of how GDP, poverty, inequality and any other concept in economics is defined. All the thresholds and all the components included in any index are arbitrary. Which income threshold determines whether a person is poor? Which transactions should be included in the computation of the GDP? One cannot answer these questions without expressing value judgments. These different measures must reflect different values and interests, and therefore concept formation is value-laden.

Thirdly, Reiss argues that modeling is value-laden because it involves making assumptions about the behavior of economic agents and the structure of the economy. Similarly to rational choice theory, these assumptions may reflect different values and interests, and it is impossible to restrain from judgments completely.

The last two points that Reiss identifies are especially important in light of recent developments in economics: hypothesis acceptance and hypothesis testing.

Hypothesis testing is value-laden because it involves selecting and interpreting data in light of theoretical assumptions. Different interpretations of data reflect values, and therefore cannot be considered purely factual. Moreover, methodological choices to test a hypothesis are also arbitrary and driven by judgments. What constitutes strong evidence or evidence at all? In economics, there seems to be a shared consensus about the answer to this question in recent years. The "credibility revolution" in economics (Angrist & Pischke, 2010) set RCTs and a few other identification strategies as the gold standard for causal analysis in economics. Qualitative approaches have been mostly abandoned and these methodological choices necessarily influence which research questions can be formulated and, more importantly, answered.

Lastly, hypothesis acceptance is impregnated with values because it involves making judgments about the relative plausibility of competing hypotheses. Economists have to make judgments because they risk accepting false hypotheses or rejecting true ones. In fact, hypothesis acceptance in modern econometrics always comes with the risk of identifying false positives or false negatives. False positives are insignificant effects incorrectly classified as significant, and false negatives are significant results incorrectly classified as insignificant. As long the statistical power is high enough (namely, the sample is sufficiently large), p-values are used to guide this decision. However, once again, the p-value thresholds are arbitrary. A result is considered significant if its p-value is below 0.1. Recent findings on p-hacking and publication bias (Brodeur, Cook, & Heyes, 2018) show how researchers strongly attempt to "improve" their p-value by continuing to collect data, re-selecting control variables, and restricting the sample. These are all attempts to enhance the chances that their research will be published because the authors show that "insignificant" results tend to be published less often. Of course, one may claim that these are community standards, meaning that economists merely accept these yet they do not make any value judgments. However, are they justified in doing so? One-size-fitsall can be dangerous. In certain cases, it might be more desirable to identify false positives than false negatives and vice-versa.[1] Or else, the hypothesis acceptance is based upon accepting some prior hypothesis (e.g., the credibility of the theoretical framework, the accurateness of the data, etc.). If economists "maneuver," possibly unconsciously, their results to adhere to said standards, they commit to various moral judgments throughout the research process.

These multiple examples show how fact-value separability is an illusion in modern economics. Economic analysis necessarily involves value judgments at every stage of the research process, and therefore cannot be considered purely factual. The positivist view of economics, which holds that economic analysis can be purely objective and value-free has been seriously challenged. Economics, thus, does not appear to be able to defend its value-freedom. Does this need that economic science needs a paradigmatic shift as Nelson suggests? To determine whether a revolution is needed, it is crucial to assess the values implicated in economics. In fact, these values could potentially be defensible or aligned with the desired goals of society. It is essential to examine whether the values implicit in economic analysis are one-sided, biased, or perpetuate certain power dynamics, as it is argued by feminist economics. Therefore, a revolution is not the only alternative. Another option would be to bite the bullet and reflect on the value judgments that inevitably shape economic research, by recognizing their existence in the first place. Economists can be transparent about the values that underlie their work, and they could adopt and endorse new practices to face this important critique.

2.3 An Account of Strong Objectivity

If economics is indeed impregnated with values and standard objectivity is unattainable, other viable options could be "strong objectivity" and "epistemic democracy." For example, Harding (1992) critiques the traditional notion of objectivity in science, arguing that it is inherently biased towards dominant social groups and is therefore incapable of achieving true objectivity. Her view is aligned with Nelson's ideas, but generalizes to science in general. Both authors challenge the traditional notion of objectivity in science and economics. They argue that traditional objectivity is limited by biases inherent in dominant social groups and that it fails to account for the social context in which knowledge is produced. They highlight the need for alternative approaches that recognize the importance of diverse perspectives and acknowledge the social construction of knowledge. In particular, Harding argues that, if one dominant group is making all the underlying value judgments in a discipline, there is a strong risk of bias and epistemic limitations. She suggests an alternative concept of "strong objectivity," which, she argues, can overcome the limitations of traditional objectivity and produce more accurate and inclusive

[1] There is an extensive and long lasting debate concerning this problem, not only restrained to the field of economics. Medicine, social sciences, and contemporary artificial intelligence and machine learning research are also all affected by this conundrum.

scientific knowledge.

Harding outlines the traditional view of objectivity in science, which she describes as a set of practices aimed at eliminating bias and subjectivity from scientific inquiry. She argues, however, that this view of objectivity is problematic because it assumes a universal, neutral standpoint from which all scientific knowledge can be objectively produced. In the case of economics, this would be the positive economics described by Friedman. In reality, she argues, scientific knowledge is produced within social contexts that are shaped by power relations and social hierarchies. This means that dominant social groups, such as white men in Western societies, have historically had greater access to scientific knowledge and have been able to shape scientific inquiry to their own ends. To address this problem, Harding proposes the concept of "strong objectivity," which she defines as a standpoint that is both radically egalitarian and strongly relativist. This means that the perspective of all social groups should be equally valued and included in scientific inquiry, rather than just the perspective of dominant groups. Moreover, scientific knowledge should be recognized as socially constructed and therefore contingent on the social context in which it is produced. If it is unattainable to achieve a neutral and objective standpoint, an alternative approach to attaining objectivity is by incorporating diverse perspectives, thus leveraging the concept of plurality. Therefore, in contrast to the conventional understanding of objectivity as a "view from nowhere," the attainment of strong objectivity entails the comprehensive integration of diverse perspectives, particularly those from historically underrepresented groups.

Strong objectivity can be achieved through a variety of practices. The inclusion of diverse perspectives in scientific inquiry, particularly those of marginalized groups who have historically been excluded from scientific knowledge production is one fundamental step in the direction of strong objectivity. Then, the social context in which scientific knowledge is produced, including the power relations and social hierarchies that shape scientific inquiry, must be recognized and examined. Furthermore, Harding emphasizes the imperative of embracing alternative research methodologies and epistemologies that are better designed to tackle the concerns of marginalized groups, while also generating knowledge that aligns with their lived experiences.

One recent proposal that addresses the practical application of strong objectivity has been presented by Jebeile (2020). Jebeile argues that the Intergovernmental Panel on Climate Change (IPCC), established with the purpose of providing governing institutions with scientific reports on climate change, is influenced by non-epistemic values, specifically contextual values. Despite being widely recognized as the preeminent authority on global warming, the IPCC is commonly perceived as an objective scientific body adhering to a value-free ideal, implying that its production and elaboration of scientific knowledge remain unbiased and grounded in neutrality. However, Jebeile contends that societal values inevitably permeate various activities within the IPCC, including data interpretation, formulation of policy recommendations, and even the dissemination of findings to the public. Consequently, these values not only impact scientific research but also the policymaking process itself. In light of this, Jebeile puts forth the notion of strong objectivity as a necessary and well-suited approach, particularly for the IPCC's operations and, more broadly, for climate change scientific research and policymaking in general. Jebeile underscores the significance of this approach in the context of climate change, which is a global challenge necessitating the involvement of scientists from diverse geographical locations, whose insights and discoveries should ideally inform global governance. The incorporation of diverse perspectives, according to Jebeile, can enhance the accuracy and comprehensiveness of our understanding, which is crucial for making informed and equitable decisions. Recognizing that knowledge is socially constructed and disseminated, Jebeile emphasizes the indispensability of diverse perspectives in the production of precise and comprehensive knowledge.

The approach advocated by Harding and Jebeile presents an opportunity for economic research to confront the inherent inseparability of facts and values, acknowledge its impossibility, and progress accordingly. Importantly, this approach does not necessarily entail discarding neoclassical economics in favor of a feminist or radical restructuring of the economic science as proposed by Nelson. However, it still calls for a more explicit recognition of value choices within the economic domain and the inclusion of diverse perspectives. The assumptions and functioning of neoclassical economics are retained while acknowledging how they came into being. Notably, fostering a more diverse research environment would be a key aspect of integrating this approach, allowing for a greater range of viewpoints to be incorporated into economic inquiry.

Therefore, a more (gender) diverse economic community could be highly beneficial, both methodologically and epistemologically. Moreover, there is at least one other compelling argument, which has been overlooked by Reiss, that supports the notion of the entanglement of fact and value in economics. This argument also presents a strong case for promoting diversity within economic research. In fact, a sixth domain where value judgments enter the economic sphere is the choice of the research field and of research questions. The reason why this was not included in Reiss' argument is likely that it does create conflict with Weber (1949). In Max Weber's ideal of Wertfreiheit (value-freedom), the focus is primarily on the research process itself being free from value judgments, rather than on the choice of research field or questions. From Weber's perspective, as long as the research is conducted in a value-free manner, the values that determine what is researched are not problematic. However, the argument for promoting diversity within economic research extends beyond the idea of value-freedom in the research process. It suggests that a more diverse economic community, encompassing a range of perspectives and preferences regarding research fields, can enhance epistemic progress and the quality of scientific discoveries. What a scientific domain is capable of discovering clearly depends on what it *attempts to discover*. Economics is divided into several sub-fields, but it is unclear which one is more epistemologically significant. The knowledge produced by economic science is the result of individual (and/or group) value judgments about the epistemic importance of certain sub-domains. Assuming that different agents have diverse preferences regarding their favorite field of study, what is the effect of diversity on epistemic progress and the quality of scientific discoveries?

3 Evolutionary Game Theory

To explore this question and investigate the epistemic desirability of diversity in economics, this chapter turns to the field of evolutionary game theory. This analytical tool offers a valuable lens for understanding the dynamics of diverse populations and their impact on collective outcomes. By allowing for the incorporation of mathematical and computational tools to simulate the dynamics of agent behavior, evolutionary game theory provides a rigorous and formal framework for modeling and analyzing strategic interactions among agents.

3.1 Related literature

Game theory is concerned with analyzing strategic interactions between agents, while evolutionary theory is concerned with the evolution of populations of organisms over time. The study of the former interests economists especially, while the study of the latter is widespread among biologists. Evolutionary game theory combines these two fields, providing a framework for analyzing how the behavior of individuals in a population evolves over time in response to the strategic behavior of others. Interestingly, evolutionary game theory has recently gained interest not only among economists, sociologists, anthropologists, and other social scientists, but also among philosophers (Alexander, 2021). This interest is due to several reasons. Firstly, the term "evolution" used in evolutionary game theory can refer to cultural evolution, i.e., changes in beliefs and norms, rather than biological evolution. Secondly, the assumptions about rationality in evolutionary game theory are often more relevant to modeling social systems than those in traditional game theory. Finally, as a dynamic theory, evolutionary game theory provides a crucial aspect that is absent in traditional game theory.

Therefore, the importance of evolutionary game theory in philosophy lies in its ability to shed light on some of the central philosophical questions, such as the nature of rationality, the emergence of social norms, and the evolution of morality. For example, evolutionary game theory can help explain why humans tend to cooperate with one another, even in situations where there is no apparent immediate benefit, and how cooperation can evolve even in the presence of self-interested agents. Recently, evolutionary game theory has been used as a tool in the field of philosophy of science, by running computer simulations. These simulations are a type of computational model that investigates the evolution of social behavior in populations of agents over time. They use mathematical and computational tools to simulate how individuals behave in social settings, based on assumptions about their goals, decision-making processes, and interactions with each others.

Weisberg and Muldoon (2009) first, and Thoma (2015) later on, successfully run such kinds of simulations to investigate the behavior of scientists in an epistemic landscape. An epistemic landscape is a metaphor for the distribution of scientific ideas across different research areas. The landscape can be visualized as a three-dimensional space, with peaks representing highly successful research programs and valleys representing less successful ones. The goal of the simulation is to investigate how the distribution and the movement of agents across the landscape affect the overall progress of science.

Weisberg and Muldoon (2009) run their simulations to study the division of cognitive labor. The authors propose an agent-based model for scientific research in which scientists explore an unknown epistemic landscape to discover the most significant research approaches. Three different search strategies are examined, including working alone without considering the discoveries of the community ("controls") and two social research strategies. The latter strategies include "followers" who are biased towards what others have already discovered and "mavericks" who attempt to explore unvisited scientific paths. The results indicate that pure populations of control scientists outperform pure populations of followers, but pure populations of mavericks are the most successful strategy. The authors also found that a mixed population of mavericks and followers can be effective for many research domains since mavericks stimulate followers to produce greater levels of epistemic output.

Thoma (2015) questioned some of the assumptions of Weisberg and Muldoon's simulation and argued that diversity in the epistemic division of labor is more beneficial than they claimed. By getting rid of the restriction to local movement and avoiding the agents merely duplicating the work of others, she finds that diversity is highly beneficial, and more so if scientists are sufficiently flexible and informed about work that is different from their own. Her model suggests the epistemic benefits of the division of labor and the potential of diverse research communities.

Therefore, the following work will run a similar evolutionary game theory simulation in order to investigate the potential benefits of a more diverse (in terms of gender diversity) economics community.

3.2 The Epistemic Landscape

As previously mentioned, an epistemic landscape is a three-dimensional space. The epistemic landscape is a theoretical representation of potential research approaches that could be pursued with regard to a particular topic, and the epistemic value that each approach holds for generating new knowledge. Contrary to Weisberg and Muldoon (2009) and Thoma (2015), the scope of each epistemic landscape presented from here on is slightly broader. While the two papers consider a single epistemic landscape as the topic that a specialized academic conference could be interested in, the epistemic landscape for the following simulations comprises the entire research field of economics. In fact, while the former landscapes were homogeneous in terms of sub-field represented, the latter is divided into three subject areas, representing the three main fields in economics: microeconomics, macroeconomics, and finance.

On the other hand, this epistemic landscape will be similar to the previous ones insofar as it is also made up of a topic (economics research in this case), various approaches (research questions, methodologies, theories), and epistemic significance, namely the relevance of a particular piece of information, evidence, or knowledge.[2] The landscape is, hence, bounded by the research topic, and the landscape's coordinates represent various approaches. Finally, the z-axis (the height of various approaches) of the landscape corresponds to the significance of each approach. The level of significance is attributed randomly to each approach (and it is reset for each new simulation), using a two-dimensional Gaussian distribution.[3] Therefore, this results in a discrete 101×101 blocks square, wrapped at the edges to form a torus, and endowed with two peaks, as shown in Figure 1.

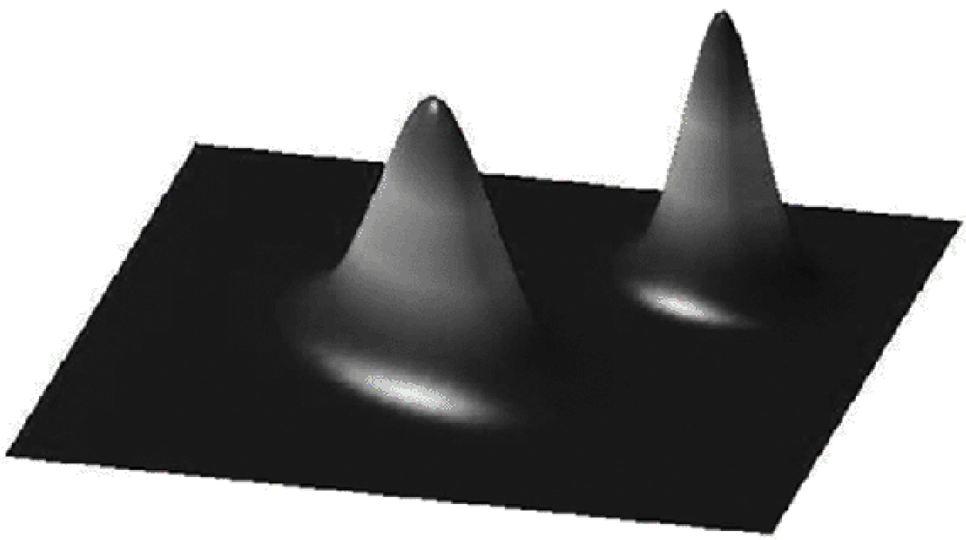

Figure 1: An example of an epistemic landscape in three-dimensions from Weisberg and Muldoon (2009).

On the other hand, Figure 2 represents a bidimensional representation of such an epistemic landscape. The yellow area represents microeconomic approaches, the red macroeconomic approaches, and the green area financial ones. The little arrows represent researchers (blue for

[2]It is important to note that an essential debate in the philosophy of science is about the origin of scientific significance. In the simulation described it is assumed that significance varies across the landscape and that the scientific community holds a uniform view of significance, with all members attributing the same level of importance to each approach. A more detailed discussion can be found in 4.

[3]A Gaussian distribution is a two-dimensional normal distribution with a function of the form $f(x,y) = A\exp\left(-a(x-x_0)^2 + b(x-x_0)(y-y_0) + c(y-y_0)^2\right)$, where A is the amplitude, (x_0, y_0) determines its center, and a, b, and c are the parameters determining the spread into its three dimensions. Just like Weisberg and Muldoon (2009), the parameters are chosen as such: $A = 0.75$, $a = 0.02$, $b = 0.01$, and $c = 0.02$ and the centre is at $(-5, -5)$.

men and pink for women). Lastly, darker areas represent less significant approaches, while the lighter the color, the more significant the approach. The lighter areas give a bi-dimensional representation of the peaks illustrated in Figure 1.

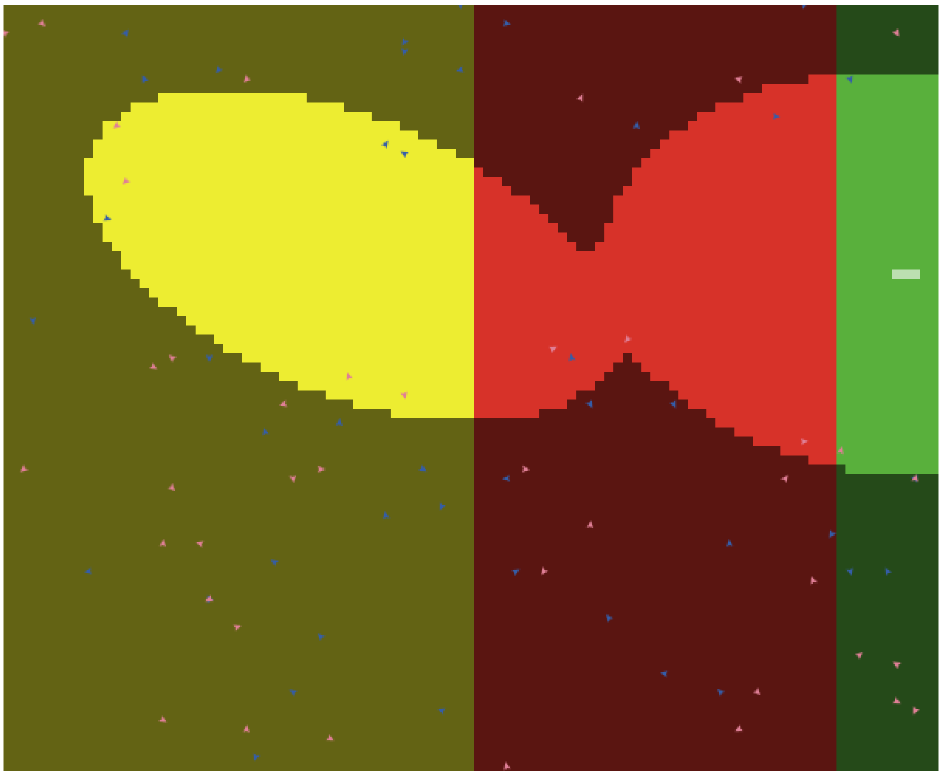

Figure 2: Economic research Epistemic Landscape

3.3 Male vs. Female Researchers

In the context of evolutionary game theory, gender diversity can have epistemological benefits for the research community as long as male and female agents are different, and have different attitudes and preferences towards research. Therefore, for the simulation, I assume that women and men have different preferences concerning their favorite sub-field of study. This assumption is backed by empirical evidence, as shown by Chari and Goldsmith-Pinkham (2018), who provide evidence of gender differences in the representation of economists across different subfields of economics. The authors explore gender representation in Economics across topics and time, using data from the NBER summer institute 2001-2018, a broad economics conference held every summer. Their data is unlikely to be perfectly representative of the entire researchers population, yet it is broad enough to draw a picture of the gender diversity status quo in the field of economics. Therefore, it can be used to inform the assumptions of these simulations.

In particular, to focus on the most recent trends in behavior, data from the years 2016-2018 is chosen. In these three years, the economics research output was split as follows: 50%

microeconomics, 40% macroeconomics, and 10% finance. Moreover, only 20% of the entire epistemic production comes from female economists. The remaining 80% is produced by men and, among them, 45% study microeconomics, 45% study macro, and 10% study finance. Interestingly, these proportions are quite different for female economists, who seem to have a strong preference for microeconomics-related topics. In fact, 60% of female economists conduct research in microeconomics, 35% in macro, and only 5% in finance.

This information is extremely useful to model the behavior of male and female agents in the epistemic landscape. Both Weisberg and Muldoon (2009) and (Thoma, 2015) acknowledge the importance of diversity in terms of epistemic labor and prove that a combination of mavericks and followers (or their "superior" version, as described by Thoma) might be epistemologically beneficial. Nonetheless, there is no empirical evidence showing how this distinction manifests itself in the economics community and whether men and women employ different behavior in this regard. Therefore, for the sake of simplicity and to avoid unfounded inferences, we assume that all agents behave like Weisberg and Muldoon's controls, regardless of their gender.

As previously mentioned, agents are spread randomly across the epistemic landscape in zero-significance patches (no significant truths to be found there) and the direction they are facing is also random. The underlying idea is that they move around looking for more significant patches. When they explore a patch, they are discovering a new portion of the epistemic landscape (or a new approach), which means they might try a new experiment, adopt a different methodology or focus on a slightly different topic altogether. For each patch, they attempt to assess whether there is a significant truth to be discovered there. If they find one, they explore it and keep on moving toward more significant patches, otherwise, they turn back and look for a more promising path. Weisberg and Muldoon's controls move following a rule they define as the "Hill-climbing with Experimentation" (HE). This means that agents follow a movement rule each round consisting of the following steps: (1) moving forward one patch, (2) comparing the significance of the current patch with the previous one, (3) if the current patch is more significant, moving forward one patch again, (4) if the current patch is equally significant, with a 2% probability, moving forward one patch with a random heading, and (5) if the current patch is less significant, moving back to the previous patch and setting a new random heading.

This is the HE algorithm determining the behavior of all agents. However, in these simulations, there is an extra condition for researchers. In fact, each agent is randomly attributed to one subfield of economics (micro, macro, finance), and they only follow the HE algorithm if they are on a patch of their own subfield. If that is not the case, they turn toward the closest patch of their favorite subfield and they start moving toward that direction. Once they arrive, then they also start adopting the HE rule in the patches of their favorite subfield.[4] This

[4]The code for the movement of an agent can be found in Appendix A1. The entire Netlogo code can be retrieved from the author.

algorithm implies that, if an agent is brought to the boundary between two subfields due to a promising significant path, they will not cross and switch subfields, but they will remain on their favorite side of the epistemic landscape. Male and female researchers are randomly attributed to one subfield of economics based on the percentages from Chari and Goldsmith-Pinkham (2018). For example, 60% of female economists will be interested in microeconomics, 35% in macroeconomics, and only 5% in finance.

In general, agents base their decisions on their own observations of the significance of a patch, and they do not consider the presence of other agents on the same patch. They tend to move in the direction of increasing significance, and if they find themselves trapped in a low-significance area, they will eventually try new directions to discover a more promising section of the epistemic landscape. Figure 3 shows an epistemic landscape after agents have started moving. The lines drawn after each agent represent their movement in the landscape and indicate the patches they have explored in their Hill-climbing activity.

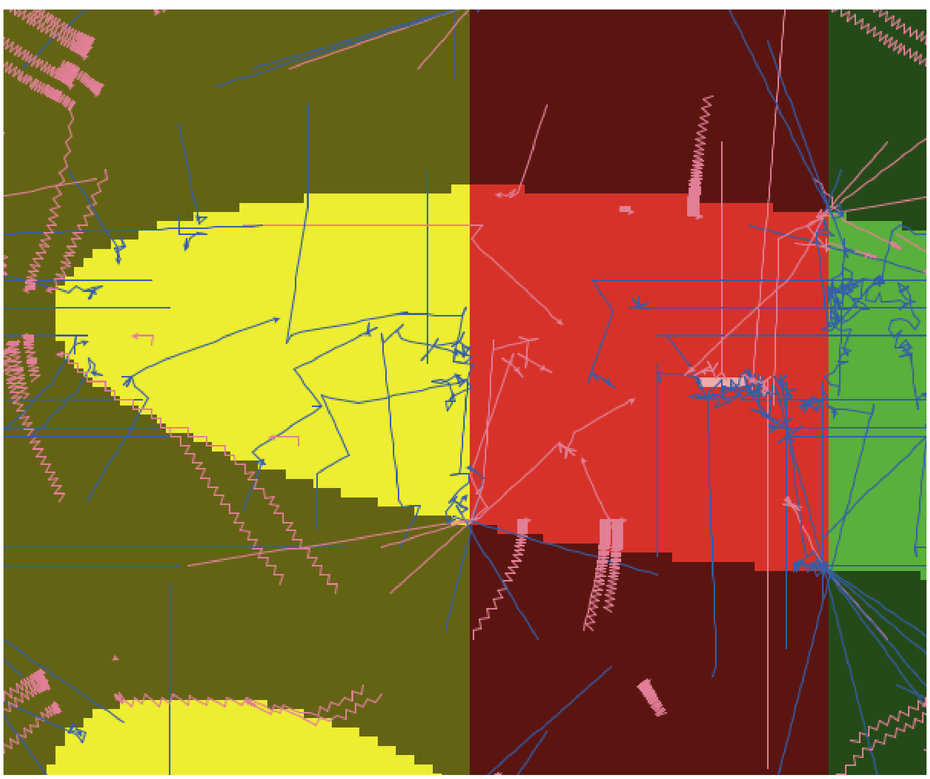

Figure 3: Economic research Epistemic Landscape - Agents' movement

3.4 Simulations

Two sets of 1000 simulations were run.[5] Each simulation lasted 200 rounds (the same number of rounds that Weisberg and Muldoon (2009) used to assess the effectiveness of each pure populations of agents) and counted 100 agents. In the first set of simulations, 80% of the agents were male researchers, and only 20% were female (status-quo according to Chari and Goldsmith-Pinkham (2018)). The second set of simulations, on the other hand, allowed for gender diversity, hence, the population of agents was split into 2 equal groups, half male and half female. Each simulation measured two outcomes: epistemic progress and quality. Epistemic progress measures the share of patches with a significance larger than 0 that were visited by at least one agent among all the patches with a significance larger than 0. Therefore, the higher the epistemic progress, the better the researcher population performed because more significant approaches have been discovered. On the other hand, quality measures the share of unvisited patches with significance bigger than 0, among all the unvisited patches. Thus, this is an indicator of the share of significant patches that were left unexplored by the agent population. The lower the percentage, the better the performance of the population. Table 1 shows some summary statistics for these two outcomes in each set of 1000 simulations.

Table 1: Summary statistics Simulations

Variable	Mean	Std. Dev.	Min	Max	Obs.
Simulations					
Status-Quo					
Epistemic Progress	0.335	0.077	0.127	0.563	1000
Quality	0.247	0.141	0.056	0.967	1000
Gender Diversity					
Epistemic Progress	0.315	0.079	0.073	0.607	1000
Quality	0.246	0.127	0.049	0.800	1000

Note: The table shows summary statistics for two sets of 1000 simulations run on NetLogo (Wilensky, 1999). Column 1 indicates the name of the outcome variable, column 2 measures the mean, column 3 measures the standard deviation, column 4 measures the minimum, column 5 measures the maximum, and column 6 measures the number of observations. The Status-Quo simulations are run with 80% male economists and 20% female economists. The Gender Diversity simulations are run with 50% male economists and 50% female economists. Epistemic progress measures the share of significant patches visited out of all significant patches. Quality measures the share of unvisited significant patches out of all unvisited patches.

[5] All the simulations are coded and run using NetLogo (Wilensky, 1999).

On average, higher epistemic progress is obtained at the status quo. On the other hand, gender diversity performs better in terms of quality. However, when a 2-sided t-test assuming unequal variances is performed to detect significant differences between the two sets of simulations, only the difference between the two means of epistemic difference is statistically significant (p-value = 0.000). On the contrary, the difference in quality is not (p-value = 0.909). Therefore, there is only enough statistical evidence to claim that the status-quo population performs better than the diverse population in terms of epistemic progress. On the other hand, there is not enough statistical evidence to confirm any difference in performance between the two populations in terms of quality.

3.5 Discussion

At first sight, therefore, it might seem that the status-quo population performs better than the diverse populations of researchers and, on average, in terms of epistemic progress, it does indeed. However, an interesting result standing out from Table 1 is that the diverse population achieves the best outcomes both in terms of epistemic progress and quality. In fact, both maximum epistemic progress (0.607) and minimum quality (0.049) are attained by the more diverse population. This result is extremely interesting because it seems to suggest that the more diverse population has greater "potential," namely, in the best-case scenario it outperforms the Status Quo. Under what conditions do the Gender Diversity simulations exhibit superior performance then? The performance of a simulation is highly dependent on the (random) distribution of significance in the epistemic landscape. When the more significant areas are mostly in the microeconomics sub-field, then the more diverse population performs exceptionally because more women economists prefer studying microeconomics-related topics. On the contrary, if finance is the more significant sub-field, then diverse populations are less effective than the status quo because very few women economists are interested in finance, and a larger share of male economists will speed up the process of scientific discovery in the finance patches.

Therefore, in terms of these evolutionary game theoretical simulations, whether a more diverse economics community is desirable depends on the significance of the various economics subfields. In recent years, economics research has undergone a significant shift towards microeconomics, with a particular focus on identifying causal relationships, namely the process of determining the cause-and-effect relationships between different economic variables or events.In economics, causal relationships are crucial for analyzing and predicting economic phenomena, policy evaluations, and understanding the impact of various factors on economic outcomes. Causal identification involves understanding how changes in one variable affect another variable, holding other factors constant (i.e., the effect of x on y, *ceteris paribus*). This shift in methodology can be traced back to what has been referred to as the "causal revolution" in economics (Angrist & Pischke, 2010), which has led to a greater emphasis on the use of rigorous methods to establish causality, such as randomized controlled trials (RCTs) and quasi-experimental analysis. RCTs, in particular, have been praised as the gold standard for evaluating policy interventions due to their ability to provide unbiased and rigorous evidence (Duflo, Glennerster, & Kremer, 2008). However, the importance of RCTs should not overshadow other research methods that can complement and strengthen their findings. In fact, quasi-experimental methods, such as natural experiments and instrumental variables, have also gained popularity as credible alternatives to RCTs in evaluating policy interventions. Overall, the shift towards microeconomics and the causal revolution in economics have greatly influenced how economic research is conducted and the methods used to establish causality. As a result, the field has become increasingly focused on identifying causal relationships and providing rigorous evidence to inform policy decisions. Therefore, this recent trend seems to strongly support the case for a more gender-diverse economic community when assessing simulations in the epistemic landscape. In fact, if microeconomics is the most significant sub-field in economics, the Gender Diversity simulations outperform the Status-quo simulations both in terms of epistemic progress and quality. Since microeconomics is imposing itself as the most prominent area of research in economics, a more gender-diverse population of research would be epistemologically beneficial, according to the results obtained through these evolutionary game theoretic simulations.

4 Limitations

All models are wrong but some are useful.

This famous quote by Box (1979) perfectly depicts how models are inherently imperfect and a mere simplification of reality. Philosophers, on the other hand, often attempt to draw a complex and complete picture of reality. Nonetheless, models can still be valuable and provide insightful information, even to philosophers. However, a fundamental step in the process of drawing inferences from models is to possess knowledge and understanding of their underlying assumptions. Models are built upon a set of assumptions that are needed to simplify the complexity of the real world. These assumptions, despite being necessary for model construction, can also introduce limitations and potential biases. Therefore, it becomes essential for philosophers to critically analyze and evaluate these assumptions. This section discusses the limitations of the evolutionary-game-theory simulations and addresses the assumptions of these simulations. By critically assessing these assumptions, we can potentially identify areas for improvement and enhance the robustness of the inferences drawn from these models. By acknowledging the imperfections of models, yet recognizing their usefulness and engaging in a critical evaluation of their assumptions, philosophers can embrace a more nuanced approach to the intersection of philosophy and economics. In fact, they can utilize the value of models while meticulously analyzing them actually to enhance our understanding of the intricate complexities of reality.

4.1 Scientific Significance

Scientific significance is the importance of a particular piece of information, evidence, or knowledge in the context of epistemology. It pertains to the impact that certain information or evidence has on our understanding, justification, or revision of beliefs and knowledge claims. The epistemic significance can be considered as the relevance of the truth that is discovered utilizing a certain approach. For the sake of simplifying the model and being able to run the simulations, the previous section was based on several assumptions about epistemic significance. In fact, it was assumed that significance varies across the landscape, according to a random distribution, and that the scientific community holds a uniform view of the epistemic significance attributed to each patch in the epistemic landscape. However, it is important to note that an essential debate in the philosophy of science is about the origin of scientific significance. There are two prominent positions within this debate. The traditional view, also known as scientific realism (Chakravartty, 2017; Putnam, 1975), suggests that certain facts possess inherent scientific significance. The more radical perspective argues that assessments of scientific significance are influenced by social, political, and ideological factors and it is referred to as social constructivism (Latour & Woolgar, 1986; Longino, 2019). Scientific realism posits that scientific significance is determined by objective criteria inherent to the nature of the scientific endeavor. According to this perspective, certain facts or discoveries are considered significant because they contribute to the advancement of knowledge, uncover fundamental truths about the natural world, or have practical implications. Proponents of this view argue that scientific significance is grounded in the inherent properties of the phenomena under investigation and the objective standards of scientific inquiry. On the other hand, social constructivism emphasizes the influence of social, political, and ideological factors on the assessment of scientific significance. This view suggests that scientific practices and the attribution of significance are shaped by dominant ideologies, cultural norms, power structures, and other social forces. According to this perspective, what is considered significant in science is not solely determined by the intrinsic properties of the research itself, but is instead influenced by societal values, interests, and biases. This debate has been central in the philosophy of science for decades and its extent and complexity go beyond the scope of this thesis. Nevertheless, it is crucial to bear in mind the complexity of this debate, as the assumptions underlying the simulations significantly oversimplify this convoluted issue.

Another major issue disregarded by the model concerns the limitations of evaluating the significance of a specific methodology or strategy without allowing for ex-post reconsiderations. One problem with evaluating the significance of a methodology ex-ante without room for ex-post reevaluation is that it assumes a static and complete understanding of the epistemic landscape. However, scientific knowledge is often incomplete and subject to revisions and updates. The true nature of the landscape may not be fully known, and unexpected discoveries or changes can occur over time. Evaluating the effectiveness of a strategy solely based on initial assumptions may overlook new information that becomes available later. In the real world, scientists may make mistakes or encounter uncertainties in their observations, measurements, or data interpretation. Think of the famous case of continental drift and plate tectonics. In the early 20th century, the prevailing scientific belief was that the continents were fixed and immovable. However, Alfred Wegener, a German scientist, proposed the theory of continental drift in 1912, suggesting that the continents were once joined together in a single landmass called Pangaea and had gradually moved apart over time. Initially, Wegener's theory was met with skepticism and faced significant resistance from the scientific community. The existing methodology for understanding the Earth's geology and the formation of landforms did not support the idea of continents drifting over millions of years. Critics argued that there was no plausible mechanism to explain how continents could move. It was not until several decades later, with advancements in technology and the accumulation of new evidence, that the theory gained wider acceptance and compelling evidence was provided for the theory of plate tectonics. This example demonstrates that scientific knowledge is not static and can evolve with new discoveries and observations. If a research strategy relies on observations or perceptions, high error rates can undermine its effectiveness. In such cases, avoiding parts of the landscape already explored by others may lead to missed opportunities. How could one deal with the incomplete and evolving nature of scientific knowledge, as well as the potential for errors and misperception in these simulations? One possibility would be to incorporate probabilistic elements into the model, allowing for the possibility of agents incorrectly perceiving the true fitness of a point on the landscape. This recognizes the inherent uncertainties and the dynamic nature of the scientific inquiry, making the model more realistic. However, this incorporation adds another layer of complexity. Yet, it could be worth exploring in future research.

4.2 Generalizability

A strong critique of the generalizability (or extrapolation) of epistemic landscapes, in general, and of the work of Weisberg and Muldoon (2009), in particular, was advanced by Alexander, Himmelreich, and Thompson (2015). First, they claim that their model fails to demonstrate the existence of epistemic justifications for cognitive diversity. They show that the movement rule (HE) for controls is quite inefficient and performs worse than populations of agents who move only in a straight line and populations of random walkers. They challenge the assumptions of the movement rules proposed by Weisberg and Muldoon (2009) and suggest they should be revisited. Clearly, this critique poses a significant challenge to the results obtained through simulations that adopt these agents. However, this problem could be addressed by improving and adapting the research strategies of the various agents. If the controls' movement shows poor performance, it can be corrected and substituted by a more accurate representation of research strategies. As previously mentioned, in the context of the diversity simulation, it would be particularly insightful to distinguish whether male and female scientists have different approaches toward these research strategies. Modeling them could result in more insightful results and improve the generalizability of the results obtained through these simulations.

Perhaps, a more interesting critique that emerges from Alexander et al. (2015) concerns the inherent generalizability of the epistemic landscape and not only of the results obtained in a certain simulation. In fact, they claim it only makes sense to say that one should employ a certain population of scientists if all epistemic landscapes are the same (or at least similar enough) and a research strategy is optimal in all of them. According to the authors, even when refining an epistemic landscape to have it possess more information and be more representative, the level of justification for generalization in these models remains unclear. For instance, the maverick strategy (preferred by Weisberg and Muldoor), may be beneficial in certain epistemic landscapes, but its effectiveness can be contingent upon various factors, such as the above-mentioned accuracy of observations and the probability of misperception, but also upon whether different disciplines require different research approaches. For instance, take the study of climate science. There are multiple sub-disciplines interested in this area of research, such as atmospheric physics, oceanography, ecology, and geology, among others. Each sub-discipline has its own unique characteristics, methodologies, and data sources. The epistemic landscape, which represents the available knowledge and methods within each sub-discipline, can, thus, vary significantly. Imagine a research strategy that aims to understand the causes and effects of climate change. In one particular epistemic landscape for one sub-discipline, for example, individual scientists who pursue innovative and unconventional research paths, potentially leading to breakthrough discoveries or alternative explanations for climate phenomena could be the most desirable. If there is a high degree of uncertainty and variability, a maverick-style strategy allows for the exploration of diverse hypotheses and methodologies. However, in another epistemic landscape within the same field, the maverick strategy might not be as fruitful. Perhaps this landscape has a more consolidated body of knowledge and a strong consensus on the key mechanisms driving climate change. In this alternative scenario, a more collaborative research strategy, namely scientists working together to refine and build upon existing theories and observations, might be more effective.

Overall, this generalizability critique revolves around the quote that introduced this chapter: models are inherently wrong. There are only a few arguments that could try to defend models from this critique. Perhaps, when models succeed at elucidating causal mechanisms they suffer less from extrapolation limitations. Yet, simulations are not very effective in this respect. It is often hard to understand the underlying mechanisms that lead to a certain result in a simulation. In general, if we seek universally generalizable findings, modeling will not provide them. However, it is important to acknowledge that, despite these limitations, modeling remains an essential and valuable tool in scientific research. Models allow us to simulate and explore complex systems and phenomena that are often difficult or impossible to study directly. They provide a means of generating hypotheses, making predictions, and (sometimes) understanding the underlying mechanisms at work. They can still offer valuable insights and understanding within specific contexts. They can help us uncover patterns, relationships, and emergent properties that may not be apparent from purely observational or experimental studies. They contribute to our understanding of the world and facilitate scientific progress.

5 Conclusion

This thesis has explored the underrepresentation of women in the field of economics and its implications for the epistemological and methodological foundations of economic theory and research. The persisting gender imbalance raises significant concerns about the validity, generalizability, and completeness of economic knowledge. By excluding diverse perspectives and alternative ways of knowing, economics may fall short of capturing the complexity of economic phenomena. Feminist economics has raised serious concerns about this imbalance, invoking a radical switch from the mainstream economic standpoint. However, it was argued that neo-classical economics does not need to perish, but it can bite the feminist bullet. By acknowledging the value-laden nature of economics and fact-value entanglement, economic research could borrow an account of strong objectivity from feminist economics. Rejecting the idea of an objective view "from nowhere," and including the viewpoint of more social groups in scientific inquiry, is an opportunity to address many biases and limitations raised by critics, and improve knowledge production. Furthermore, not only diversity is methodologically desirable to face these shortcomings, but the inclusion of diverse researchers could improve epistemic progress. By employing agent-based evolutionary game theoretic simulations, it was shown that a more gender-diverse economic community could achieve better epistemic progress and quality of knowledge production. In fact, diverse agent populations outperform status-quo populations when microeconomics is the sub-field with the highest epistemic significance in the simulation. In light of recent trends in economic research and the "causal revolution" in economics, there is strong a case to be advocated for with regard to the significance of applied microeconomics in contemporary research. Although these simulations have limitations, they provide insights into the positive effects of increased gender diversity on epistemic outcomes. Furthermore, several of these limitations could be addressed by constructing more realistic models in future research.

Diversity in economics is desirable, both methodologically and epistemologically. By embracing a strong objectivity framework and fostering an inclusive research community, economics can enhance its understanding of economic phenomena and contribute to addressing real-world challenges more effectively.

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A Appendix

Snippet A.1: Agent movement

The following code shows the rule for the movement of a male agent whose favorite subfield is Microeconomics

```
to move-man-micro
  let current-patch patch-here
  let current-color [pcolor] of current-patch
  let target-patch patch-ahead 1
  let target-color [pcolor] of target-patch
  let heading-back heading - 180  ; calculate the heading to
     move back
  let patch-behind patch-at-heading-and-distance heading-back 1
      ; get patch behind agent
  ; determine desired color based on probabilities
  let random-number random 100
  let desired-color ""
  set desired-color yellow
if ([pcolor] of current-patch = desired-color) [
    ifelse ([significance] of patch-here) >=
       previous_significance [
      ifelse ([significance] of patch-here) =
         previous_significance [
        if random 50 = 1 [
          set previous_significance ([significance] of
             patch-here)
          set heading random 360
            ifelse (target-color = desired-color)[
              fd 1
          ]
            [
              fd 0
              set heading random 360
            ]
          ]
        ]
```

```
      [
        set previous_significance ([significance] of patch-here)
         ifelse (target-color = desired-color)[
              fd 1
        ]
            [
              fd 0
              set heading random 360
            ]
      ]
    ]
    [
      ifelse ([pcolor] of patch-behind = desired-color) [
      back 1
      set heading random 360
            ]
      [
         fd 0
         set heading random 360
        ]
  ]
  ]
  if ([pcolor] of current-patch != desired-color) [
   let closest-patch min-one-of patches with [pcolor =
      desired-color] [distance current-patch] ; find closest
      patch of desired color
    if closest-patch != nobody [
    face closest-patch ; turn towards closest patch
    fd 1 ; move towards closest patch
  ]
  ]

end
```