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Statistical Characteristics of Breakthrough Discoveries in Science Using the Metaphor of Black and White Swans

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Highlights

1. We define "black swan" and "white swans" against the background of the history of scientific research.

2. We describe how the "black swan" has become a metaphor for scientific breakthroughs and how its appearance changes the citation patterns of "white swans."

3. We combine scientific discovery with scientometric data to verify the accuracy of the qualitative and quantitative indications of a breakthrough discovery

Abstract: *A publication that reports a breakthrough discovery in a particular scientific field is referred to as a "black swan", and the most highly-cited papers previously published in the same field "white swans". Important scientific progress occurs when "white swans" meet a "black swan", and the citation patterns of the "white swans" change. This metaphor combines scientific discoveries and scientometric data and suggests that important scientific discoveries are either "black swans" or "grey-black swans".*

Keywords: *scientific discovery; breakthrough discovery; white swan; black swan; grey swan*

1. Introduction

Before black swans were discovered in Australia, Europeans believed that all swans were white. The discovery of black swans changed this belief. Extending this to science, breakthrough discoveries that change scientific views and promote scientific progress are the "black swans" [1] of research.

Unlike black swans in art or economics, black swans in science have no benefit of hindsight. When white swans meet a black swan, only scientific views are changed.

The philosophy of science [2] indicates that scientific discoveries may cause scientific revolutions and promote scientific progress[3]. With the advent of citation analysis[4] we know more about the inheritance and transformation of scientific knowledge[5], and the new

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