Probability as input or output of a social science model?

Emmanuel Haven - FBA and IQSCS - Memorial University, Canada.

Nov. 2018
Objectives of our talk

- I am not a physicist
Objectives of our talk

- I am not a physicist
- Rather I work in economics and finance
Objectives of our talk

- I am not a physicist
- Rather I work in economics and finance
- This talk will be concerned about briefly discussing:

  i) some finance/economics models which make no use of any 'wave based' formalism
  ii) some finance/economics models which do make use of an aspect of 'wave based' formalism

Positioning the 'wave function'

Examples

a) Markov model versus QP model in Ellsberg paradox
b) Bottom up economics: reactivity
Objectives of our talk

- I am not a physicist
- Rather I work in economics and finance
- This talk will be concerned about briefly discussing:
  - i) some finance/economics models which make no use of any ‘wave based’ formalism
  - ii) some finance/economics models which do make use of an aspect of ‘wave based’ formalism

Examples

a) Markov model versus QP model in Ellsberg paradox
b) Bottom up economics: reactivity
Objectives of our talk

- I am not a physicist
- Rather I work in economics and finance
- This talk will be concerned about briefly discussing:
  1) some finance/economics models which make no use of any ‘wave based’ formalism
  2) some finance/economics models which do make use of an aspect of ‘wave based’ formalism!
  Positioning the ‘wave function’!
  Examples
  a) Markov model versus QP model in Ellsberg paradox
  b) Bottom up economics: reactivity

Objectives of our talk

- I am not a physicist
- Rather I work in economics and finance
- This talk will be concerned about briefly discussing:
  - i) some finance/economics models which make no use of any ‘wave based’ formalism
  - and
  - ii) some finance/economics models which do make use of an aspect of ‘wave based’ formalism
Objectives of our talk

- I am not a physicist
- Rather I work in economics and finance
- This talk will be concerned about briefly discussing:
  - i) some finance/economics models which make no use of any ‘wave based’ formalism
  - and
  - ii) some finance/economics models which do make use of an aspect of ‘wave based’ formalism
- → Positioning the ‘wave function’
Objectives of our talk

- I am not a physicist
- Rather I work in economics and finance
- This talk will be concerned about briefly discussing:
  i) some finance/economics models which make no use of any ‘wave based’ formalism
  and
  ii) some finance/economics models which do make use of an aspect of ‘wave based’ formalism
  → Positioning the ‘wave function’
  → Examples
Objectives of our talk

• I am not a physicist
• Rather I work in economics and finance
• This talk will be concerned about briefly discussing:
  • i) some finance/economics models which make no use of any ‘wave based’ formalism
  • and
  • ii) some finance/economics models which do make use of an aspect of ‘wave based’ formalism
• → Positioning the ‘wave function’
• → Examples
• →→ a) Markov model versus QP model in Ellsberg paradox
Objectives of our talk

- I am not a physicist
- Rather I work in economics and finance
- This talk will be concerned about briefly discussing:
  i) some finance/economics models which make no use of any ‘wave based’ formalism
  and
  ii) some finance/economics models which do make use of an aspect of ‘wave based’ formalism
- → Positioning the ‘wave function’
- → Examples
- →→ a) Markov model versus QP model in Ellsberg paradox
- →→ b) Bottom up economics: reflexivity
Objectives of our talk

- c) when not looking: the ‘less randomness’ case
Objectives of our talk

- c) when not looking: the ‘less randomness’ case
- c1) example 1
Objectives of our talk

- c) when not looking: the ‘less randomness’ case
- c1) example 1
- c2) example 2 (the macroscopic lab setting)
Objectives of our talk

- c) when not looking: the ‘less randomness’ case
- c1) example 1
- c2) example 2 (the macroscopic lab setting)
- c3) example 3 (public information differentiation)
Objectives of our talk

- c) when not looking: the 'less randomness' case
  - c1) example 1
  - c2) example 2 (the macroscopic lab setting)
  - c3) example 3 (public information differentiation)
- Conclusion
i) Finance/economics models with no wave formalism

- Let us look at three groups of examples
i) Finance/economics models with no wave formalism

- Let us look at three groups of examples
- **Group 1: traditional economics stance versus behavioral approach: top down versus bottom up**
Let us look at three groups of examples

**Group 1: traditional economics stance versus behavioral approach: top down versus bottom up**

In the traditional economics approach (f.i. American School with Arrow and Radner and others) we do not look at the individual and we avoid formalizing the intricate relations between individuals: top down approach.
Let us look at three groups of examples

**Group 1: traditional economics stance versus behavioral approach: top down versus bottom up**

In the traditional economics approach (f.i. American School with Arrow and Radner and others) we do not look at the individual and we avoid formalizing the intricate relations between individuals: top down approach

**Example of top down: Rational expectations (R. Lucas) in economics**
Let us look at three groups of examples

**Group 1: traditional economics stance versus behavioral approach: top down versus bottom up**

In the traditional economics approach (f.i. American School with Arrow and Radner and others) we do not look at the individual and we avoid formalizing the intricate relations between individuals: top down approach

**Example of top down: Rational expectations (R. Lucas) in economics**

Here the economy is represented as being ‘one individual’
Let us look at three groups of examples

**Group 1: traditional economics stance versus behavioral approach: top down versus bottom up**

In the traditional economics approach (f.i. American School with Arrow and Radner and others) we do not look at the individual and we avoid formalizing the intricate relations between individuals: top down approach

**Example of top down: Rational expectations (R. Lucas) in economics**

Here the economy is represented as being ‘one individual’

We know future prices of assets are uncertain
i) Finance/economics models with no wave formalism

- Let us look at three groups of examples

- **Group 1: traditional economics stance versus behavioral approach: top down versus bottom up**

  - In the traditional economics approach (f.i. American School with Arrow and Radner and others) we do not look at the individual and we avoid formalizing the intricate relations between individuals: *top down approach*

  - **Example of top down: Rational expectations (R. Lucas) in economics**

  - Here the economy is represented as being ‘one individual’

  - We know future prices of assets are uncertain

  - But, within rational expectations, decision makers are assumed to have identical distributions on those future prices
i) Finance/economics models with no wave formalism

- Let us look at three groups of examples
- **Group 1: traditional economics stance versus behavioral approach: top down versus bottom up**
  - In the traditional economics approach (f.i. American School with Arrow and Radner and others) we do not look at the individual and we avoid formalizing the intricate relations between individuals: top down approach
  - **Example of top down: Rational expectations (R. Lucas) in economics**
    - Here the economy is represented as being ‘one individual’
    - We know future prices of assets are uncertain
    - But, within rational expectations, decision makers are assumed to have identical distributions on those future prices
    - *The model informs the probability: i) assume identical distributions and; ii) the distribution is...*
Example of bottom up in economics
Example of bottom up in economics

Kirman remarks: start from the individual and make a model on the interaction of individuals (behavioral economics)
i) Finance/economics models with no wave formalism (cont’d)

- **Example of bottom up in economics**
- Kirman remarks: start from the individual and make a model on the interaction of individuals (behavioral economics)
- For instance in Kirman’s ‘ant recruitment’ model (a model then grafted into economics), he considers how ants recruit other ants to go to a particular food source
Example of bottom up in economics

Kirman remarks: start from the individual and make a model on the interaction of individuals (behavioral economics)

For instance in Kirman’s ‘ant recruitment’ model (a model then grafted into economics), he considers how ants recruit other ants to go to a particular food source

When the ants do interact to varying degrees, his model is the source for different probability outcomes: a martingale for instance
i) Finance/economics models with no wave formalism (cont’d)

- **Example of bottom up in economics**
- Kirman remarks: start from the individual and make a model on the interaction of individuals (behavioral economics)
- For instance in Kirman’s ‘ant recruitment’ model (a model then grafted into economics), he considers how ants recruit other ants to go to a particular food source
- When the ants do interact to varying degrees, his model is the source for different probability outcomes: a martingale for instance
- *The model informs the probability*
i) Finance/economics models with no wave formalism (cont’d)

- Group 2: finance approach - options (absence of individuals)
i) Finance/economics models with no wave formalism (cont’d)

- **Group 2: finance approach - options (absence of individuals)**
  - The celebrated option pricing model in finance, stays clear of any individual decision making
Group 2: finance approach - options (absence of individuals)

- The celebrated option pricing model in finance, stays clear of any individual decision making
- The resultant formulation for a call option, for instance, is a difference between two cumulative distribution functions
i) Finance/economics models with no wave formalism (cont’d)

- **Group 2: finance approach - options (absence of individuals)**
- The celebrated option pricing model in finance, stays clear of any individual decision making
- The resultant formulation for a call option, for instance, is a difference between two cumulative distribution functions
- *The model informs the probability*
Group 3: finance approach non observed probabilities
i) Finance/economics models with no wave formalism (cont’d)

- **Group 3: finance approach non observed probabilities**
- Andrei mentions in one of his latest papers that we do sometimes not separate two layers of mathematical modelling of natural and mental phenomena
i) Finance/economics models with no wave formalism (cont’d)

- **Group 3: finance approach non observed probabilities**
- Andrei mentions in one of his latest papers that we do sometimes not separate two layers of mathematical modelling of natural and mental phenomena
- An example of the so called sub-observational model are the risk neutral probabilities in finance
Group 3: finance approach non observed probabilities

Andrei mentions in one of his latest papers that we do sometimes not separate two layers of mathematical modelling of natural and mental phenomena.

An example of the so called sub-observational model are the risk neutral probabilities in finance.

A non-observed probability, \( \tilde{P} : E^{\tilde{P}} [(\exp(-r_f t)S_t|S_u, u < t] \)
i) Finance/economics models with no wave formalism (cont’d)

- **Group 3: finance approach non observed probabilities**
- Andrei mentions in one of his latest papers that we do sometimes not separate two layers of mathematical modelling of natural and mental phenomena
- An example of the so called sub-observational model are the risk neutral probabilities in finance
- A non-observed probability, \( \tilde{P} \): 
  \[ E^{\tilde{P}} \left[ (\exp(-r_f t)S_t \mid S_u, u < t \right] \]
- *The model informs the probability*
ii) Can wave formalism be part of the model? Positioning the ‘wave function’

- this is not a classical wave: it has no energy and lives in a space which is not $\mathbb{R}^3$ for instance
ii) Can wave formalism be part of the model? Positioning the ‘wave function’

- this is not a classical wave: it has no energy and lives in a space which is not $\mathbb{R}^3$ for instance
- the probability wave is an integral part of the probability formalism in quantum probabilities
ii) Can wave formalism be part of the model? Positioning the ‘wave function’

- this is not a classical wave: it has no energy and lives in a space which is not $\mathbb{R}^3$ for instance
- the probability wave is an integral part of the probability formalism in quantum probabilities
- the probability wave stands (Heisenberg) in “the middle between the idea of an event and the actual event”
ii) Can wave formalism be part of the model? Positioning the ‘wave function’

- this is not a classical wave: it has no energy and lives in a space which is not $\mathbb{R}^3$ for instance
- the probability wave is an integral part of the probability formalism in quantum probabilities
- the probability wave stands (Heisenberg) in “the middle between the idea of an event and the actual event
- quantum physics delivers a consistent calculus of probability for a certain kind of experiment involving a system and apparatus (Susskind)
ii) Can wave formalism be part of the model? Positioning the ‘wave function’

- there is contextual interaction between what is measured and the measuring apparatus
ii) Can wave formalism be part of the model? Positioning the ‘wave function’

- there is contextual interaction between what is measured and the measuring apparatus
- a measurement outcome is ‘actualized’ among a set of possible outcomes, as a consequence of this contextual interaction

See preface to our special issue in the Journal of Mathematical Economics (on quantum probability theory and its economic applications)
ii) Can wave formalism be part of the model? Positioning the ‘wave function’

- there is contextual interaction between what is measured and the measuring apparatus
- a measurement outcome is ‘actualized’ among a set of possible outcomes, as a consequence of this contextual interaction
- this contextual interaction is non-controllable (and generates the Heisenberg uncertainty principle)
ii) Can wave formalism be part of the model? Positioning the ‘wave function’

- there is contextual interaction between what is measured and the measuring apparatus
- a measurement outcome is ‘actualized’ among a set of possible outcomes, as a consequence of this contextual interaction
- this contextual interaction is non-controllable (and generates the Heisenberg uncertainty principle)
- a possible premise (for social science use): human judgments and decisions are constructive processes
ii) Can wave formalism be part of the model? Positioning the ‘wave function’

- there is contextual interaction between what is measured and the measuring apparatus
- a measurement outcome is ‘actualized’ among a set of possible outcomes, as a consequence of this contextual interaction
- this contextual interaction is non-controllable (and generates the Heisenberg uncertainty principle)
- a possible premise (for social science use): human judgments and decisions are constructive processes
- in which the interaction between the object of the decision and the decision maker is of a cognitive nature (rather than physical nature)
ii) Can wave formalism be part of the model? Positioning the ‘wave function’

- there is contextual interaction between what is measured and the measuring apparatus
- a measurement outcome is ‘actualized’ among a set of possible outcomes, as a consequence of this contextual interaction
- this contextual interaction is non-controllable (and generates the Heisenberg uncertainty principle)
- a possible premise (for social science use): human judgments and decisions are constructive processes
- in which the interaction between the object of the decision and the decision maker is of a cognitive nature (rather than physical nature)
- See preface to our special issue in the Journal of Mathematical Economics (on quantum probability theory and its economic applications)
ii) Can wave formalism be part of the model? Positioning the ‘wave function’

- there is contextual interaction between what is measured and the measuring apparatus
- a measurement outcome is ‘actualized’ among a set of possible outcomes, as a consequence of this contextual interaction
- this contextual interaction is non-controllable (and generates the Heisenberg uncertainty principle)
- a possible premise (for social science use): human judgments and decisions are constructive processes
  in which the interaction between the object of the decision and the decision maker is of a cognitive nature (rather than physical nature)
- See preface to our special issue in the Journal of Mathematical Economics (on quantum probability theory and its economic applications)
- Quantum probability expresses a deeper level of uncertainty?
Examples of wave formalism: a) Markov model versus QP model

- The Ellsberg paradox is a good example where the quantum formalism in social science has been applied.
Examples of wave formalism: a) Markov model versus QP model

- The Ellsberg paradox is a good example where the quantum formalism in social science has been applied
- see the work by protagonists present here in this meeting: Andrei/Jerome/Ehti/Acacio and others
Examples of wave formalism: a) Markov model versus QP model

- The Ellsberg paradox is a good example where the quantum formalism in social science has been applied.
- see the work by protagonists present here in this meeting: Andrei/Jerome/Ehti/Acacio and others
- Two approaches were proposed: a Markov approach and a quantum-like approach.
Examples of wave formalism: a) Markov model versus QP model

- The Ellsberg paradox is a good example where the quantum formalism in social science has been applied
- see the work by protagonists present here in this meeting: Andrei/Jerome/Ehti/Acacio and others
- Two approaches were proposed: a Markov approach and a quantum-like approach
- In the Markov approach: the probability of gambling in the unknown case is supposed to be equal to the average of the probabilities of gambling in the known cases. This is not the case.
Examples of wave formalism: a) Markov model versus QP model

- The Ellsberg paradox is a good example where the quantum formalism in social science has been applied
- see the work by protagonists present here in this meeting: Andrei/Jerome/Ehti/Acacio and others
- Two approaches were proposed: a Markov approach and a quantum-like approach
- In the Markov approach: the probability of gambling in the unknown case is supposed to be equal to the average of the probabilities of gambling in the known cases. This is not the case.
- As has been shown now by many authors, the quantum-like model can accommodate observed percentages by using the probability interference term
Examples of wave formalism: a) Markov model versus QP model

- The Ellsberg paradox is a good example where the quantum formalism in social science has been applied
- see the work by protagonists present here in this meeting: Andrei/Jerome/Ehti/Acacio and others
- Two approaches were proposed: a Markov approach and a quantum-like approach
- In the Markov approach: the probability of gambling in the unknown case is supposed to be equal to the average of the probabilities of gambling in the known cases. This is not the case.
- As has been shown now by many authors, the quantum-like model can accommodate observed percentages by using the probability interference term
- Quantum-like is defined how though? Wave as carrier of information? A deeper level of uncertainty?
Examples of wave formalism: b) bottom up economics: reflexivity

- Recall we mentioned top down economics, where we avoid formalizing interaction between decision makers.
Examples of wave formalism: b) bottom up economics: reflexivity

- Recall we mentioned top down economics, where we avoid formalizing interaction between decision makers.
- In the bottom up approach, we exactly do this, but now with the idea of a wave function.

Soros argues that in his theory of reflexivity, the economic agent's thinking, has two functions: i) "...to understand reality; that is the cognitive function" and ii) "to make an impact on the situation...(the) manipulative, function". If both functions, in the words of Soros, do "operate simultaneously (then) they interfere with each other". It is this interference that Soros calls 'reflexivity'. When both functions interfere, they produce uncertainty in both the participants' understanding and the actual course of events.
Examples of wave formalism: b) bottom up economics: reflexivity

- Recall we mentioned top down economics, where we avoid formalizing interaction between decision makers.
- In the bottom up approach, we exactly do this, but now with the idea of a wave function.
- Soros argues that in his theory of reflexivity, the economic agent’s thinking, has two functions: i) “...to understand reality; that is the cognitive function” and ii) “to make an impact on the situation...(the) manipulative, function”
Examples of wave formalism: b) bottom up economics: reflexivity

- Recall we mentioned top down economics, where we avoid formalizing interaction between decision makers.
- In the bottom up approach, we exactly do this, but now with the idea of a wave function.
- Soros argues that in his theory of reflexivity, the economic agent’s thinking, has two functions: i) “...to understand reality; that is the cognitive function” and ii) “to make an impact on the situation...(the) manipulative, function”
- If both functions, in the words of Soros, do “operate simultaneously (then) they interfere with each other”. It is this interference that Soros calls ‘reflexivity’.
Examples of wave formalism: b) bottom up economics: reflexivity

- Recall we mentioned top down economics, where we avoid formalizing interaction between decision makers.
- In the bottom up approach, we exactly do this, but now with the idea of a wave function.
- Soros argues that in his theory of reflexivity, the economic agent’s thinking, has two functions: i) “...to understand reality; that is the cognitive function” and ii) “to make an impact on the situation...(the) manipulative, function”
- If both functions, in the words of Soros, do “operate simultaneously (then) they interfere with each other”. It is this interference that Soros calls ‘reflexivity’.
- When both functions interfere, they produce uncertainty in both the participants’ understanding and the actual course of events.
Examples of wave formalism: b) bottom up economics: reflexivity

- The interference works as a feedback loop: positive feedback reinforces both the prevailing trend and the prevailing bias — and leads to a mispricing of financial assets.
Examples of wave formalism: b) bottom up economics: reflexivity

- The interference works as a feedback loop: positive feedback reinforces both the prevailing trend and the prevailing bias — and leads to a mispricing of financial assets.
- Negative feedback corrects the bias.
Examples of wave formalism: b) bottom up economics: reflexivity

- The interference works as a feedback loop: positive feedback reinforces both the prevailing trend and the prevailing bias — and leads to a mispricing of financial assets.
- Negative feedback corrects the bias.
- We could identify the existence of a negative (or positive) feedback with the width of an amplitude function.
Examples of wave formalism: b) bottom up economics: reflexivity

- The width of the resultant wave function, we will propose, can be used as an indicator of the degree of erroneous information.
Examples of wave formalism: b) bottom up economics: reflexivity

- The width of the resultant wave function, we will propose, can be used as an indicator of the degree of erroneous information.
- Under positive feedback: since trend and bias are reinforced: the trend is quite well known.
Examples of wave formalism: b) bottom up economics: reflexivity

- The width of the resultant wave function, we will propose, can be used as an indicator of the degree of erroneous information.
- Under positive feedback: since trend and bias are reinforced: the trend is quite well known.
- The slope of the trend is the momentum (see Brownian motion for instance) and hence that trend is known with good certainty.
Examples of wave formalism: b) bottom up economics: reflexivity

- The width of the resultant wave function, we will propose, can be used as an indicator of the degree of erroneous information.
- Under positive feedback: since trend and bias are reinforced: the trend is quite well known.
- The slope of the trend is the momentum (see Brownian motion for instance) and hence that trend is known with good certainty.
- The amplitude function on the wave number is tight and, via Fourier integration, this would create a very wide wave function.

If this wave function is dependent on price, the probability of mispricing would be high indeed (noise trading).
Examples of wave formalism: b) bottom up economics: reflexivity

- The width of the resultant wave function, we will propose, can be used as an indicator of the degree of erroneous information.
- Under positive feedback: since trend and bias are reinforced: the trend is quite well known.
- The slope of the trend is the momentum (see Brownian motion for instance) and hence that trend is known with good certainty.
- The amplitude function on the wave number is tight and, via Fourier integration, this would create a very wide wave function.
- If this wave function is dependent on price, the probability of mispricing would be high indeed (noise trading).
Examples of wave formalism: b) bottom up economics: reflexivity

- Implicitly, we are using information in our discussion
Examples of wave formalism: b) bottom up economics: reflexivity

- Implicitly, we are using information in our discussion.
- It can be noted that in the top down approach to explain how out of equilibrium pricing (mispricing) will become equilibrium pricing (correct pricing).
Examples of wave formalism: b) bottom up economics: reflexivity

- Implicitly, we are using information in our discussion.
- It can be noted that in the top down approach to explain how out of equilibrium pricing (mispricing) will become equilibrium pricing (correct pricing).
- It was shown by Saari and Simon, to require infinite amount of information.
Examples of wave formalism: b) bottom up economics: reflexivity

- Implicitly, we are using information in our discussion
- It can be noted that in the top down approach to explain how out of equilibrium pricing (mispricing) will become equilibrium pricing (correct pricing)
- It was shown by Saari and Simon, to require infinite amount of information
- The approach here, is bottom up: positive or negative feedback effects are linked to levels of erroneous information
Examples of wave formalism: c) when not looking: the ‘less randomness’ case

- This less randomness case is also known as Bohmian mechanics
Examples of wave formalism: c) when not looking: the ‘less randomness’ case

- This less randomness case is also known as Bohmian mechanics
- I understand it as electrons travelling through paths (some definiteness (because of paths))
Examples of wave formalism: c) when not looking: the ‘less randomness’ case

- This less randomness case is also known as Bohmian mechanics
- I understand it as electrons travelling through paths (some definiteness (because of paths))
- In fact - Holland tells us that:
Examples of wave formalism: c) when not looking: the ‘less randomness’ case

- This less randomness case is also known as Bohmian mechanics
- I understand it as electrons travelling through paths (some definiteness (because of paths))
- In fact - Holland tells us that:
- the superposition principle does not enter into the idea of multiplicity of paths
Examples of wave formalism: c) when not looking: the ‘less randomness’ case

- This less randomness case is also known as Bohmian mechanics
- I understand it as electrons travelling through paths (some definiteness (because of paths))
- In fact - Holland tells us that:
  - the superposition principle does not enter into the idea of multiplicity of paths
- but - rather - into the idea of a unique path the particle takes between two points
Examples of wave formalism: c) when not looking: the ‘less randomness’ case

- This less randomness case is also known as Bohmian mechanics.
- I understand it as electrons travelling through paths (some definiteness (because of paths)).
- In fact - Holland tells us that:
  - the superposition principle does not enter into the idea of multiplicity of paths.
- but - rather - into the idea of a unique path the particle takes between two points.
- AND
Examples of wave formalism: c) when not looking: the ‘less randomness’ case

- This less randomness case is also known as Bohmian mechanics
- I understand it as electrons travelling through paths (some definiteness (because of paths))
- In fact - Holland tells us that:
  - the superposition principle does not enter into the idea of multiplicity of paths
  - but - rather - into the idea of a unique path the particle takes between two points
- AND
- it is then subject to nonclassical effects due to the quantum potential
Examples of wave formalism: c) when not looking: the ‘less randomness’ case

- Within the physics community this is not regarded upon as an interesting interpretation of quantum mechanics.
Examples of wave formalism: c) when not looking: the ‘less randomness’ case

- Within the physics community this is not regarded upon as an interesting interpretation of quantum mechanics.
- But it does have very useful features, especially for economics and finance.
Examples of wave formalism: c) when not looking: the ‘less randomness’ case

- Within the physics community this is not regarded upon as an interesting interpretation of quantum mechanics
- But it does have very useful features, especially for economics and finance
- Andrei was the first to suggest (almost 19 years ago) its use in social science
Examples of wave formalism: c) when not looking: the ‘less randomness’ case

- Within the physics community this is not regarded upon as an interesting interpretation of quantum mechanics
- But it does have very useful features, especially for economics and finance
- Andrei was the first to suggest (almost 19 years ago) its use in social science
- The wave function is still linked to probability but now also guides the particle
When not looking: the ‘less randomness’ case: c1) example 1 (Hawkins)

Let $x_0$ be the true price, and let the $x_{obs}$ be the observed price, with fluctuations $x$: $x_{obs} = x_0 + x$
When not looking: the ‘less randomness’ case: c1) example 1 (Hawkins)

- Let $x_0$ be the true price, and let the $x_{obs}$ be the observed price, with fluctuations $x$: $x_{obs} = x_0 + x$
- Fluctuations $x$ indicate uncertainty on $x_0$
When not looking: the ‘less randomness’ case: c1)

example 1 (Hawkins)

- Let $x_0$ be the true price, and let the $x_{obs}$ be the observed price, with fluctuations $x$: $x_{obs} = x_0 + x$
- Fluctuations $x$ indicate uncertainty on $x_0$
- To represent fluctuation: use the probability amplitude $\psi(x)$; probability $P(x, t) = |\psi(x, t)|^2$
When not looking: the ‘less randomness’ case: c1) example 1 (Hawkins)

- Let $x_0$ be the true price, and let the $x_{\text{obs}}$ be the observed price, with fluctuations $\xi$: $x_{\text{obs}} = x_0 + \xi$
- Fluctuations $\xi$ indicate uncertainty on $x_0$
- To represent fluctuation: use the probability amplitude $\psi(x)$; probability $P(x, t) = |\psi(x, t)|^2$
- Hawkins and Frieden show that by optimizing Fisher information s.t. to the condition probabilities sum to 1
Let \( x_0 \) be the true price, and let the \( x_{obs} \) be the observed price, with fluctuations \( x \): \( x_{obs} = x_0 + x \)

Fluctuations \( x \) indicate uncertainty on \( x_0 \)

To represent fluctuations: use the probability amplitude \( \psi(x) \); probability \( P(x, t) = |\psi(x, t)|^2 \)

Hawkins and Frieden show that by optimizing Fisher information s.t. to the condition probabilities sum to 1

an equation is obtained which is akin to the Schrödinger equation:

\[
\frac{d^2 \psi(x)}{dx^2} = -\frac{1}{4} \left[ \lambda_0 + \sum_{m=1}^{M} \lambda_m f_m(x) \right] \psi(x)
\]
Let $x_0$ be the true price, and let the $x_{obs}$ be the observed price, with fluctuations $x$: $x_{obs} = x_0 + x$

- Fluctuations $x$ indicate uncertainty on $x_0$
- To represent fluctuations: use the probability amplitude $\psi(x)$; probability $P(x, t) = |\psi(x, t)|^2$
- Hawkins and Frieden show that by optimizing Fisher information s.t. to the condition probabilities sum to 1
- An equation is obtained which is akin to the Schrödinger equation:
  $$\frac{d^2\psi(x)}{dx^2} = -\frac{1}{4} \left[ \lambda_0 + \sum_{m=1}^{M} \lambda_m f_m(x) \right] \psi(x)$$
- Where $\lambda_0$ is the Lagrangian multiplier and $\lambda_m f_m(x)$ plays the role of the potential
When not looking: the ‘less randomness’ case: c1) example 1 (Hawkins)

- Let $x_0$ be the true price, and let the $x_{obs}$ be the observed price, with fluctuations $x$: $x_{obs} = x_0 + x$
- Fluctuations $x$ indicate uncertainty on $x_0$
- To represent fluctuation: use the probability amplitude $\psi(x)$; probability $P(x, t) = |\psi(x, t)|^2$
- Hawkins and Frieden show that by optimizing Fisher information s.t. to the condition probabilities sum to 1
- an equation is obtained which is akin to the Schrödinger equation:
  $$\frac{d^2 \psi(x)}{dx^2} = -\frac{1}{4} \left[ \lambda_0 + \sum_{m=1}^{M} \lambda_m f_m(x) \right] \psi(x)$$
  where $\lambda_0$ is the Lagrangian multiplier and $\lambda_m f_m(x)$ plays the role of the potential
- For instance, this real potential could be an option intrinsic value
When not looking: the ‘less randomness’ case: c1)
example 1 (Hawkins)

- Fisher information is also linked to the quantum potential of Bohm
When not looking: the ‘less randomness’ case: c1) example 1 (Hawkins)

- Fisher information is also linked to the quantum potential of Bohm
- Average value of the quantum potential is proportional to Fisher information
Recently Couder, Fort, Bush and others have established that droplets of silicone oil (using a vibrating oil surface) can walk laterally in the so-called 'walker' exhibiting wave-particle duality. In a double slit experiment, the walker droplet passes through one slit or the other, while the guiding wave passes through both, causing the droplet to feel the second slit by virtue of a pilot wave (see Bush (2015)). The motion of a droplet is driven by an interaction with a superposition of waves emitted by the points the droplet has visited previously. Brady and Anderson show that the droplets follow an analogue of the Schrödinger equation (with a constant of motion which is not $\hbar$-of course).
Recently Couder, Fort, Bush and others have established that droplets of silicone oil (using a vibrating oil surface) can walk laterally. The so called ‘walker’ exhibits wave particle duality.
Recently Couder, Fort, Bush and others have established that droplets of silicone oil (using a vibrating oil surface) can walk laterally.

The so-called ‘walker’ exhibits wave particle duality.

In a double slit experiment: walker droplet passes through one slit or the other.
Recently Couder, Fort, Bush and others have established that droplets of silicone oil (using a vibrating oil surface) can walk laterally.

The so-called ‘walker’ exhibits wave-particle duality.

In a double slit experiment: walker droplet passes through one slit or the other.

The guiding waves pass through both slits: walker droplet feels second slit by virtue of pilot wave (see Bush (2015)).
Recently Couder, Fort, Bush and others have established that droplets of silicone oil (using a vibrating oil surface) can walk laterally.

The so-called ‘walker’ exhibits wave particle duality.

In a double slit experiment: walker droplet passes through one slit or the other.

The guiding waves pass through both slits: walker droplet feels second slit by virtue of pilot wave (see Bush (2015)).

The motion of a droplet is driven by an interaction with a superposition of waves emitted by the points the droplet has visited previously.
Recently Couder, Fort, Bush and others have established that droplets of silicone oil (using a vibrating oil surface) can walk laterally.

The so-called ‘walker’ exhibits wave particle duality.

In a double slit experiment: walker droplet passes through one slit or the other.

The guiding waves pass through both slits: walker droplet feels second slit by virtue of pilot wave (see Bush (2015)).

The motion of a droplet is driven by an interaction with a superposition of waves emitted by the points the droplet has visited previously.

Brady and Anderson show that the droplets follow an analogue of the Schrödinger equation (with a constant of motion which is not $\hbar$ - of course).
When not looking: the ‘less randomness’ case: c2)

example 2 (the macroscopic lab setting)

- Nieuwenhuizen mentions that this quantum-like behavior, as found in the lab, ‘proves the possibility that true quantum behavior originates from classical stochastic forces.’
Nieuwenhuizen mentions that this quantum-like behavior, as found in the lab, 'proves the possibility that true quantum behavior originates from classical stochastic forces.'

If this were true - it is powerful: this means that there is a firm green light to interpret classical stochastic forces as inputs to information (recall the relation between quantum potential and Fisher information)
Nieuwenhuizen mentions that this quantum-like behavior, as found in the lab, ‘proves the possibility that true quantum behavior originates from classical stochastic forces.’

If this were true - it is powerful: this means that there is a firm green light to interpret classical stochastic forces as inputs to information (recall the relation between quantum potential and Fisher information)

This model is holding great potential as an explicit formalism to model information in an economics/finance setting
Recently, Chen Shen and Tahmasebi et al. have estimated potentials (real and quantum) from commodity data.
Recently, Chen Shen and Tahmasebi et al. have estimated potentials (real and quantum) from commodity data.

Some interesting results came forward (and more work is currently performed).
Quantum potential - between the walls, the curve is relatively flat
Quantum potential - between the walls, the curve is relatively flat.

No equilibrium point.
When not looking: the ‘less randomness’ case: c3
example 3 (public information differentiation)

- Quantum potential - between the walls, the curve is relatively flat
- No equilibrium point
- Classical potential: close to an inverted bell shape curve
When not looking: the ‘less randomness’ case: c3)
example 3 (public information differentiation)

- Quantum potential - between the walls, the curve is relatively flat
- No equilibrium point
- Classical potential: close to an inverted bell shape curve
- There is an equilibrium point
When not looking: the ‘less randomness’ case: c3) example 3 (public information differentiation)

- If the returns try to jump well out of range, a strong negative reaction force will pull those returns back
When not looking: the ‘less randomness’ case: c3)

example 3 (public information differentiation)

- If the returns try to jump well out of range, a strong negative reaction force will pull those returns back.
- Both forces (blue is force linked to quantum potential) restrict the variation of returns in a range.
When not looking: the ‘less randomness’ case: c3) example 3 (public information differentiation)

- If the returns try to jump well out of range, a strong negative reaction force will pull those returns back.
- Both forces (blue is force linked to quantum potential) restrict the variation of returns in a range.
- Non-zero slope indicates some sort of mechanism: which keeps returns within bounds (in fact check bottom of quantum potential versus bottom of real potential).
For in-range values, gradient of force associated to real potential is larger than the gradient of force associated to quantum potential.
When not looking: the ‘less randomness’ case: c3) example 3 (public information differentiation)

- For in-range values, gradient of force associated to real potential is larger than the gradient of force associated to quantum potential
- Two types of public information?
We have mentioned in other talks that many fundamental properties from physics won’t hold in economics and finance.
Conclusion

- We have mentioned in other talks that many fundamental properties from physics won't hold in economics and finance.
- Conservation is an issue.
Conclusion

- We have mentioned in other talks that many fundamental properties from physics won’t hold in economics and finance.
- Conservation is an issue.
- Time reversibility is an issue.
Conclusion

- We have mentioned in other talks that many fundamental properties from physics won't hold in economics and finance
- Conservation is an issue
- Time reversibility is an issue
- Hermiticity is an issue
We have mentioned in other talks that many fundamental properties from physics won't hold in economics and finance. Conservation is an issue. Time reversibility is an issue. Hermiticity is an issue. For instance, the Hamiltonian of Black-Scholes is non-Hermitian.
How much physics formalism do we need?

- For my own purposes, I do not find this difficult
For my own purposes, I do not find this difficult.

There is a macroscopic lab tested analogue of pilot wave theory which has good propensity.
For my own purposes, I do not find this difficult

- There is a macroscopic lab tested analogue of pilot wave theory which has good propensity
- for applications in economics, as an information modelling ‘machine’
How much physics formalism do we need?

- For my own purposes, I do not find this difficult.
- There is a macroscopic lab tested analogue of pilot wave theory which has good propensity.
- for applications in economics, as an information modelling ‘machine’
- Also in other areas:
How much physics formalism do we need?

- For my own purposes, I do not find this difficult.
- There is a macroscopic lab tested analogue of pilot wave theory which has good propensity.
- For applications in economics, as an information modelling ‘machine’.
- Also in other areas:
- Finally, we did not discuss 'Why quantum' in this talk. This is the title of a chapter in Andrei’s Handbook (Palgrave MacMillan) where quantum in biology is discussed.


