Introductory lectures of an advanced course on Marxist Science

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MOTIVATION

Marxism is a science not an ideology.

You can only understand how to do Marxist research if you understand the scientific method.

In my introductory lectures I give an account of how the scientific method works with examples largely drawn from Physics.

I use Physics because it is

a) The most fundamental of the sciences
b) Marx explicitly claimed to be aiming to derive ‘laws of motion’ of capitalism, so the methods of physics seem applicable.
c) Many advances in the last 30 years have come from applying physics concepts to Marxian political economy.
The scientific method is the process by which scientists, collectively and over time, endeavour to construct an accurate (reliable, consistent and non-arbitrary) representation of the world.

It is also phenomenally successful, and without which we would not have most of the advanced technologies we now take for granted.
• A sequence or collection of processes that are considered characteristic of scientific investigation
• The acquisition of new scientific knowledge based upon physical evidence
• Science deals with assertions about the way the world is, through theories, hypotheses or observations
• The scientific method underlies the practice of science, enabling the community to determine which theories, hypotheses and observations are valid.
The Scientific Method

Elements

A body of techniques for:
● investigating phenomena
● acquiring new knowledge
● correcting and integrating previous knowledge.

It is based on:
● gathering observable, empirical and measurable evidence
● subject to specific principles of reasoning
● the collection of data through observation and experimentation
● and the formulation and testing of hypotheses.
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  - Religious beliefs and myths
  - Racial and national prejudices
  - Class prejudices
Effect of prejudice

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*To advance science must overcome these prejudices*
The Scientific Method

This is a stable closed system, it persists and does not change for centuries or millenia.
Mythological Astronomy -
  Lay observation – the sun, moon, and what we call planets move through the sky
  Religious mode of thought – gods exist
  Mythological explanation –
    Apollo rides a burning chariot through the sky each day,
    Luna is pulled by two bulls through the sky once a month,
    Mars, Venus, Mercury, etc are the other 'visible gods'.
The 'truth' of myths

Stability from closure

It explains the observations

- we can see that Apollo actually does move through the sky
- we know we really do rely on his heat to survive, Hence we obviously must worship him
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These seem naïve now, but in their day they were obvious truths. Think how many 'new age' beliefs of this sort are replicated on the Internet.
Pre-socratics critique the mythological approach and give a variety of purely mechanical explanations.
Pythagorean science

Accounts for then known main features of planetary motions.
- Explains lunar and solar eclipses
- Explains the movement of sun through the houses of the zodiac.
- Explains main movement of the planets towards the east.

Does not explain retrograde motion, once discovered this creates problem – CONTRADICTION in paradigm

“Number rules the universe.” (Pythagoras)
Paradigm refinement – normal science

With Ptolemy's epicycle model we have a mature scientific theory that correctly predicts the visible positions of the sun moon and planets hundreds of years ahead. Accurate estimate of distance of the moon – 29.5 earth diameters as opposed to current estimate of 30 earth diameters, Underestimates distance to the sun.

Here we have a stable scientific paradigm – unshaken for 1400 years
Paradigm shifts, Kuhn, Bachelard

Myth → Epistemological break → Scientific paradigm

geocentric paradigm

Refine paradigm

New data (retrograde motion)
Paradigm shifts, Kuhn, Bachelard

Myth

Epistemological break

Scientific paradigm

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New data (retrograde motion)

Accumulation of anomalies
Too many epicycles

Paradigm shift

Eliptical heliocentrism
Paradigm shifts, Kuhn, Bachelard

Myth → Epistemological break → Scientific paradigm

- Refine paradigm
  - geocentric paradigm
    - New data (retrograde motion)
  - Refine paradigm
    - Heliocentric paradigm
      - New data (comets)

Accumulation of anomalies → Paradigm shift

- Eliptical heliocentrism
  - Refine paradigm
    - With gravity
Explainable anomalies

Normal Science

Le Verrier

Newtonian space paradigm

Refine paradigm With Neptune

New data (anomalous orbit of Saturn)
Big Anomalies lead to shifts

Newtonian space paradigm

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New data (anomalou s orbit of Saturn)

Other anomalies Michaelson Morely, orbit of Mercury

Relativistic Paradigm
Acceptance after confirmation

Newtonian space paradigm
Refine paradigm With Neptune
New data (anomalously orbit of Saturn)

Le Verrier

Relativistic Paradigm
Prediction
Gravity bends light

Eddington eclipse experiment

Normal Science

Revolutionary Science

Paradigm shift

Other anomalies
Michaelson Morely, orbit of Mercury
Note that prior to Einstein nobody would have thought of doing the experiment that Eddington did. Huge expense and trouble, traveling to site of distant total eclipse and then careful angular measurements.
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If you were not working in the relativistic paradigm it would never occur to you to make the observation. This is why Gaston Bachelard calls it a 'problematique' since it determines the very problems that scientists pose themselves.
Empirical proof of hypothesis

This is the actual image Eddington took. Einstein was right!

The plate superimposes starfield before and after the eclipse, showing effect of the Sun’s gravity on apparent positions of stars.
New anomalies can arise
Conflicting explanations

According to Newton's laws the orbital velocity of a body is lower the further it is from its parent.

But for Galaxies this does not seem to be the case – orbital velocities are either flat or increasing.

Either:
a) there is a lot of matter that we can not see ie not as stars of ionised gas, the so called Dark Matter Hypothesis.
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F = ma  \quad \text{(Newton's law)}

Replaced by

F = m\mu \left(\frac{a}{a_0}\right) a \quad \text{(Milgrom's law)}

Where \(\mu \left(\frac{a}{a_0}\right) = \frac{1}{1+a_0/a}\)

And \(a_0\) is a fundamental constant \(= 1.2 \times 10^{-8} \text{ cm s}^{-2}\)
Example rotation curve of one normal high-surface-brightness galaxy (NGC 6503, ).
(Left): Three-parameter dark-halo fit (solid curve). The rotation curve of the stellar (dashed line), gas (dotted line), and dark-halo (dash-dotted line) components are shown. The fitting parameters are the M/L ratio of the disk, the halo core radius, and the halo asymptotic velocity.
(Right): The MOND fit showing the one-parameter fit (M/L). Velocities in km/s and radius in kpc.
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Which is true?
Ptolemy's theory or Newton?
Both gave good predictions, and explained observations with a causal model.

Advantage of Newton – greater explanatory power – same theory for apples as for planets. Explains comets as well as planets, used to predict the existence of Uranus.

Advantage of Ptolemy, simple to calculate, can be automated easily, good enough for all terrestrial purposes like navigation, finding longitude etc.

We can now be certain heliocentrism is correct because we navigate probes to Jupiter using it, but before the space age there was there practical proof?
Nomenclature

- A hypothesis is a limited statement regarding cause and effect in specific situations; it also refers to our state of knowledge before experimental work has been performed and perhaps even before new phenomena have been predicted.
- A model is a simple physical embodiment of a more complex reality that can be used to make precise predictions about that reality.
A scientific theory or law represents a hypothesis, or a group of related hypotheses, which has been confirmed through repeated experimental tests. This becomes the *dominant paradigm*.

- Theories in physics are often formulated in terms of a few concepts and equations, which are identified with "laws of nature," suggesting their universal applicability.
- In Historical Materialism we have theories of similar standing such as Marx theory of value.
- In computer science we have Alan Turing’s limits of computability.
Iterations and recursions of the following four steps:

- Ruling paradigm characterises the data
- Hypothesis (a tentative model or proposed explanation of prior observations)
- Prediction (logical deduction from the hypothesis)
- Experiment (test all of the above)

This process is subject to evaluation by the scientists directly involved, or by the scientific community, at any or every stage.

A theory of proposal is accepted only after it has become known to others (via peer-reviewed publication) and criticised.

Deviation of a study from accepted scientific practice is grounds for its rejection as pseudoscience.
Characterisation:
- The subject of the investigation must be characterized through careful measurement and the use of formal definitions of relevant concepts.

Hypothesis:
- Includes a suggested explanation of the subject, and will generally provide a causal explanation or propose some correlation.
Prediction:
- An essential feature of a useful hypothesis is the ability to deduce predictions that can be experimentally assessed

- If the experimental results contradict (refute) the predictions, the hypothesis under test is incorrect or incomplete, i.e. falsified

- If the results confirm (support) the hypothesis, the hypothesis might be correct, but is always subject to further tests.

Experiment:
- Once a prediction is made, an experiment is designed to test it; the experiment may seek either confirmation or falsification of the hypothesis.
Characterisation

- Observation and description of a phenomenon or group of phenomena
- You don’t have to do this yourself of course!
  - Many “problems” are already documented in the literature to greater or lesser extent
  - Gives rise to the Problem Definition
  - However this can be problematic if the phenomenon in question is not well understood – how does one define it?

- This is absolutely central to Scientific Advance. The Marxist Philosopher Althusser says the Problematic or Problem Definition is what marks a science.
Hypothesis Development

● The hypothesis must be testable
  ● Theories which cannot be tested, because they have no observable ramifications, do not qualify as scientific theories.

● For example: superstring “theory” is controversial since the string phenomena occur at an incredibly small scale – beyond the observable reach of current technology or any currently conceivable future technology.

● The motivation to test a theory, often drives the development of new technology for so doing, e.g. the development of ever larger particle colliders to attempt to find “Higgs Boson” a very high energy particle predicted by the Standard Model in particle physics
Popper also argues that a hypothesis must be *falsifiable* to be a proper scientific theory

- It must be possible at least in principal that an observation could render the hypothesis false, even if it has not yet been made.
- In other words, it must be possible to show that the predictions of the hypothesis do not guarantee its own success by definition.

**Problem**: the ruling paradigm may so structure your thought that you can not conceptualise how it may be false.

*If the above may seem abstract, consider a problem you might want to tackle.*

- Could you formulate a testable and falsifiable hypothesis in your chosen domain?

*Although Popper argued that Marxism was non falsifiable and thus not scientific, this argument was demolished by Cornforth who gives multiple examples of potentially falsifiable predictions in historical materialism.*
Example

≺ Hyp 1: “The moon is populated by little green men who can read our minds and will hide whenever anyone on earth looks for them, and will flee into deep space whenever a spacecraft comes near”

≺ Hyp 2: “There are no little green men on the moon”

≺ Hyp 1 is not falsifiable. While Hyp 2 is scientific: you can disprove it by catching one green man 🙂
Occam’s Razor

● How to select competing hypotheses?

● Occam’s razor is a “device” that says we should select the simplest hypothesis that is consistent with experimental observations

● E.g. consider the following competing hypotheses:
  • No 1: “Smoke observed (from Earth) on the surface of Mars is due to dust clouds raised by the Martian atmosphere”
  • No 2: “Smoke observed (from Earth) on the surface of Mars is due to bonfires lit by Martian Aliens to celebrate the outcome of their political elections”
  • Occam’s razor rejects Hypothesis 2 as having greater complexity than hypothesis 1, even though hypothesis 2 was actually proposed in the press! (albeit a long time ago)
Occam’s Razor (2)

● **Another Example:**
  ● Hyp 1: “The planets move around the sun in ellipses because there is a force between any of them and the sun which decreases as the square of the distance.”
  ● Hyp 2: “The planets move around the sun in ellipses because there is a force between any of them and the sun which decreases as the square of the distance. This force is generated by the will of the god Zeus.”

● Both hypotheses posit the same type of force, and therefore make the same prediction
● Hyp2 has an additional baggage (the will of Zeus), which is unnecessary for the description of the system
● Rejecting Hyp2 guards against dramatic consequences
Albert Einstein said that the universe should be explained as simply as possible, but no simpler...

In other words, the most plausible hypothesis is the simplest which is consistent with prior observations and subsequent experimental outcomes

Occam’s razor does not say anything about the truth of a hypothesis, only how to rank it relative to other competing hypotheses

- i.e. this does NOT rule out the competing hypotheses, it merely establishes priorities
Prediction

- A hypothesis that cannot make predictions is of limited value.
- A useful hypothesis could provide predictions in terms of experimental outcomes or natural phenomena.
- It is essential that the outcome is currently unknown:
  - From the set of predictions it is then possible to design experiments to test the hypothesis.
Transparency:
- Scientists assume an attitude of openness and accountability on the part of those conducting an experiment.

Experimental Records:
- Detailed recordkeeping is essential
- Aids in recording and reporting on the experimental results
- Provides evidence of the effectiveness and integrity of the procedure
- Assist in reproducing experimental results

Reproducibility:
- If the experiment appears successful, then the results are published in a way that allows others to reproduce the same experiments and results.
In the scientific method, an experiment is a set of actions and observations, performed to verify or falsify a hypothesis or look for a causal relationship between phenomena.

Experimental design attempts to balance the requirements and limitations of the scientific field in one work so that the experiment can provide the best conclusions about the hypothesis under test.

When all conditions cannot be controlled, statistical methods are employed.
• Many predictions are of the form “X causes Y”; experiments to test these types of predictions must be carefully designed in order to determine the validity of the assertion of causality
  • i.e. we have a free X variable and a causal variable Y and a hypothesis that makes predictions about their relationship.

• In the “hard sciences”, the experiments usually attempt to define an independent variable corresponding to “X” that can be varied, to hold all other variables constant, and to measure “Y” as one varies the independent variable.

• In the “soft sciences”, the experiments introduce a control – i.e. two virtually identical experiments are run, in only one of which the factor being tested is varied – e.g. the control group when testing the efficacy of a drug
Common Mistakes

✗ Being so convinced by a hypothesis (obvious “common sense” outcome) that it appears unnecessary to test it.
  ✗ An example is Marxists never bothering to test the equalisation of the rate of profit hypothesis in Marx
✗ Ignore data that does not support the hypothesis as “outliers” or “noise” or “systematic error” and over-acceptance of data that does support the expected outcome.
✗ Failure to estimate quantitatively systematic errors and all other errors.
✗ Failure to notice a new phenomenon in the experimental data by explaining it away as noise or systematic error.
✗ Bias through preference of a specific hypothesis.
A scientific model is a machine for predicting how part of reality will behave.

We tend to think of models in an abstract conceptual sense, I want to argue that we should look at them in a very concrete material sense.

I will present historical examples, and then formulate criteria for the ‘goodness’ of models, before applying these general principles to economic modeling.

The whole approach is very computational.
The basic modelling process

Initial observations

The model

Predictions

Comparison

Other observations

Reality
Are models ‘ideas’ or are they machines?

Newton Thinks…

NASA computes…
But were they thoughts?

Or were they always something material, produced by physical work using physical tools?

Illustration from the *Principia*

Ptolemy’s epi-cycle model is well known, but it is equivalent to Apollonius’s Cycle and Deferent Model.
In 1900 a group of sponge divers sheltering from a storm anchored off the island of Antikythera. Diving from there they spotted an ancient shipwreck with bronze and marble statuary visible. Further diving in 1902 revealed what appeared to be gearwheels embedded in rock. On recovery these were found to be parts of a complicated mechanism, initially assumed to be a clock. Starting in the 1950s and going on to the 1970s the work of Price established that it was not a clock but some form of calendrical computer. Using X-rays, modern reconstructions have been built showing that it physically implemented Appolonius’s model of the lunar orbit.
The original machine dates from the 2\textsuperscript{nd} century BC but modern reconstructions have been built. I show a particularly beautiful one by Tania van Vark. You turn the handle and get predictions of the position of the sun and moon in the sky and the dates of eclipses. It emphasises how a scientific model is a \textit{microcosm} emulating a \textit{macrocosm}. 
Since the invention of the Universal Computer in the 1940s, it was no longer necessary to build special purpose mechanical models of physical system.

A universal computer is a physical device that can be configured to simulate any physical process.

It is configured by the input of an appropriate mathematical function representing the model.

Deutsch’s principle

‘Every finitely realizable physical system can be perfectly simulated by a universal model computing machine operating by finite means’.

Key principles of modelling

· **Generation of testable predictions**
  - A model which makes no testable predictions is useless

· **Elegance or simplicity**
  - Occam’s Razor ‘Entities should not be multiplied without cause’.
The statements of science are not about concrete everyday objects but about abstract theoretical entities.
- The geometry of Euclid for example discusses abstract objects like points, angles etc,
- Thermodynamics discusses temperature and entropy,
- But we can not see points, or entropy with our senses.
Mathematically we can view any use of a model as 
\[(p,d) \leftarrow M(d)\]
Where \(p\) are the predictions, \(M\) is the function encoding the model, and \(d\) are the input data.
After running the model we have both the predictions and the original data.
For the model to be elegant we want to maximise its information yield 
\[Y = \frac{I(p)}{I(M)}\]
Where \(I(x)\) means the information content of \(x\)
For the model to be useful we want to maximise the mutual information in the predictions \( p \), and observed system \( o \).

\[
\text{Max } I(p; o) = H(p) - H(p|o)
\]

Where \( H(p) \) is the uncertainty or entropy in \( p \) and \( H(p|o) \) is the uncertainty in \( p \) given \( o \).

Whilst minimising the information in the model \( I(M) \).

That is to say we should avoid models that contain a lot of internal information – in the worst case such a model simply tabulates the observations.
Why entropy?

- In the formula to find mutual information we used the H function for entropy. Why?
- Surely entropy has to do with thermodynamics which studies things like the efficiency steam engines?
- Yes, but a key discovery of the 20th century was how information and entropy are linked.

The model Newcomen steam engine, now in the Hunterian Museum Glasgow University, on which James Watt worked in 1765, and from which his invention of the separate condenser came.
The Basic Problem of Information

- What is information?
- How does it relate to entropy?
- Clausius – no process possible that has the sole effect of transferring heat from a colder to a hotter body.
Gas initially in equilibrium. Daemon opens door only for fast molecules to go from A to B, or slow ones from B to A. Slow molecules in A, fast in B. B hotter than A, and can be used for power. Information has produced power!
Maxwell's proposed counter-example to the second law was explicitly based on atomism. With Boltzmann, entropy is placed on an explicitly atomistic foundation, in terms of an integral over molecular phase space.

\[ S = -k \int f(v) \log f(v) \, dv \]

where \( v \) denotes volume in six-dimensional phase space, \( f(v) \) is the function that counts the number of molecules present in that volume, and \( k \) is Boltzmann's constant.
The communications engineer Shannon introduces the concept of entropy as being relevant to sending messages by teletype. The mean information content of an ensemble of messages is obtained by weighting the log of the probability of each message by the probability of that message. He showed that no encoding of messages in 1s and 0s could be shorter than this, this is essentially the same as Boltzmann’s formula.

\[ H = - \sum_{i=1}^{n} p_i \log_2 p_i \]

Hence information = entropy.
Information measured in bits provides a common means of measuring both the model M and the predictions p.

- Suppose we have a vector of observations O which we have reason to believe are given to an accuracy of 3 digits. Then each observation contains
  \[ \log_2(1000) \approx 10 \text{ bits} \]
- Suppose we have a prediction vector P which we assume is to the same accuracy. We can estimate \( H(P|O) \) by histograming the distribution of the ratio \( P/O \) and then applying Shannon’s entropy formula to the distribution

\[
H(S) = - \sum p_i \log_2 p_i,
\]
If we want to compare models, we can decompose each of the models into two parts

1. A basic structure or formula
2. A set of auxiliary parameters or constants that has to be provided

Each of these can be given an information measure. The formula is measurable in terms of the number of bits needed to write it down as a string of digital characters.

The parameters are measurable in terms of the number of parameters and the accuracy in bits to which each has to be given.
Models and Laws

Sciences designate as laws those models that:
1. Have a simple, elegant formulation with few parameters
2. Make excellent predictions in an apparently unlimited number of cases
Applying this to economics

One may ask how much of what is taught in undergraduate bourgeois economics consists of

a) Empirically testable and empirically tested propositions
b) Formulae that are elegant and simple
c) Simple formulae that are so universal and excellent in their predictive power as to deserve the name Laws.