# Introducing the Computational Economics "Algorithmic Repository and toolKit" github.com/econ-ark

Presentation by Chris Carroll and Matthew White at CESIfo Conference, Venice

June, 2017

State-of-the-art set of tools for:

State-of-the-art set of tools for:

Simulating behavior of populations of agents

State-of-the-art set of tools for:

- Simulating behavior of populations of agents
- Solving dynamic stochastic optimization problems

State-of-the-art set of tools for:

- Simulating behavior of populations of agents
- Solving dynamic stochastic optimization problems
  - Particularly adapted for Bellman problems with 'kinks' and quirks

• Heterogeneous Agent Macro Models

- Heterogeneous Agent Macro Models
  - Original name: Heterogeneous Agent Resources and toolKit

- Heterogeneous Agent Macro Models
  - Original name: Heterogeneous Agent Resources and toolKit
  - HARK!

- Heterogeneous Agent Macro Models
  - Original name: Heterogeneous Agent Resources and toolKit
  - HARK!
- Structural Micro Models (e.g., labor, health)

- Heterogeneous Agent Macro Models
  - Original name: Heterogeneous Agent Resources and toolKit
  - HARK!
- Structural Micro Models (e.g., labor, health)
- IO models with optimizing consumers and firms

- Heterogeneous Agent Macro Models
  - Original name: Heterogeneous Agent Resources and toolKit
  - HARK!
- Structural Micro Models (e.g., labor, health)
- IO models with optimizing consumers and firms
- Not Only About Heterogeneous stuff ...

- Heterogeneous Agent Macro Models
  - Original name: Heterogeneous Agent Resources and toolKit
  - HARK!
- Structural Micro Models (e.g., labor, health)
- IO models with optimizing consumers and firms
- Not Only About Heterogeneous stuff ...
- ... Algorithmic Resources and toolKit

- Heterogeneous Agent Macro Models
  - Original name: Heterogeneous Agent Resources and toolKit
  - HARK!
- Structural Micro Models (e.g., labor, health)
- IO models with optimizing consumers and firms
- Not Only About Heterogeneous stuff ...
- ... Algorithmic Resources and toolKit
- :-)

- Heterogeneous Agent Macro Models
  - Original name: Heterogeneous Agent Resources and toolKit
  - HARK!
- Structural Micro Models (e.g., labor, health)
- IO models with optimizing consumers and firms
- Not Only About Heterogeneous stuff ...
- ... Algorithmic Resources and toolKit
- :-)
  - Unlike Noah's, our ARK can hold more than two of each kind!

- Heterogeneous Agent Macro Models
  - Original name: Heterogeneous Agent Resources and toolKit
  - HARK!
- Structural Micro Models (e.g., labor, health)
- 10 models with optimizing consumers and firms
- Not Only About Heterogeneous stuff ...
- ... Algorithmic Resources and toolKit
- :-)
  - Unlike Noah's, our ARK can hold more than two of each kind!
  - Ultimate goal: Get examples on the ARK of all types of animal (model)

github.com/econ-ark is the project's home

Get a GitHub account. Then, options to access are

- Get a GitHub account. Then, options to access are
  - Install GitHub Desktop App

- Get a GitHub account. Then, options to access are
  - Install GitHub Desktop App
  - Install 'git' command-line tool (if you're hard-core)

- Of Get a GitHub account. Then, options to access are
  - Install GitHub Desktop App
  - Install 'git' command-line tool (if you're hard-core)
- 2 github.com/econ-ark/HARK is a "public repo"

- Of Get a GitHub account. Then, options to access are
  - Install GitHub Desktop App
  - Install 'git' command-line tool (if you're hard-core)
- github.com/econ-ark/HARK is a "public repo"
  - Contains all existing code

- Get a GitHub account. Then, options to access are
  - Install GitHub Desktop App
  - Install 'git' command-line tool (if you're hard-core)
- 2 github.com/econ-ark/HARK is a "public repo"
  - Contains all existing code
- github.com/econ-ark/HARK/Documentation/NARK.pdf

- Of Get a GitHub account. Then, options to access are
  - Install GitHub Desktop App
  - Install 'git' command-line tool (if you're hard-core)
- 2 github.com/econ-ark/HARK is a "public repo"
  - Contains all existing code
- github.com/econ-ark/HARK/Documentation/NARK.pdf
  - Describes variable naming conventions for easy workflow:

- Get a GitHub account. Then, options to access are
  - Install GitHub Desktop App
  - Install 'git' command-line tool (if you're hard-core)
- 2 github.com/econ-ark/HARK is a "public repo"
  - Contains all existing code
- github.com/econ-ark/HARK/Documentation/NARK.pdf
  - Describes variable naming conventions for easy workflow:
  - LaTeX object definitions correspond to HARK definitions

- Get a GitHub account. Then, options to access are
  - Install GitHub Desktop App
  - Install 'git' command-line tool (if you're hard-core)
- 2 github.com/econ-ark/HARK is a "public repo"
  - Contains all existing code
- github.com/econ-ark/HARK/Documentation/NARK.pdf
  - Describes variable naming conventions for easy workflow:
  - LaTeX object definitions correspond to HARK definitions
- Similar structure will be used for future contributions

- Of Get a GitHub account. Then, options to access are
  - Install GitHub Desktop App
  - Install 'git' command-line tool (if you're hard-core)
- 2 github.com/econ-ark/HARK is a "public repo"
  - Contains all existing code
- github.com/econ-ark/HARK/Documentation/NARK.pdf
  - Describes variable naming conventions for easy workflow:
  - LaTeX object definitions correspond to HARK definitions
- Similar structure will be used for future contributions
  - Agent Archive Repository Deposit Vehicle for ARK?

- Get a GitHub account. Then, options to access are
  - Install GitHub Desktop App
  - Install 'git' command-line tool (if you're hard-core)
- 2 github.com/econ-ark/HARK is a "public repo"
  - Contains all existing code
- github.com/econ-ark/HARK/Documentation/NARK.pdf
  - Describes variable naming conventions for easy workflow:
  - LaTeX object definitions correspond to HARK definitions
- Similar structure will be used for future contributions
  - Agent Archive Repository Deposit Vehicle for ARK?
- Instructions for cloning are in the README.txt

- Of Get a GitHub account. Then, options to access are
  - Install GitHub Desktop App
  - Install 'git' command-line tool (if you're hard-core)
- 2 github.com/econ-ark/HARK is a "public repo"
  - Contains all existing code
- github.com/econ-ark/HARK/Documentation/NARK.pdf
  - Describes variable naming conventions for easy workflow:
  - LaTeX object definitions correspond to HARK definitions
- Similar structure will be used for future contributions
  - Agent Archive Repository Deposit Vehicle for ARK?
- Instructions for cloning are in the README.txt
- You get the whole codebase under the Apache license

- Of Get a GitHub account. Then, options to access are
  - Install GitHub Desktop App
  - Install 'git' command-line tool (if you're hard-core)
- 2 github.com/econ-ark/HARK is a "public repo"
  - Contains all existing code
- github.com/econ-ark/HARK/Documentation/NARK.pdf
  - Describes variable naming conventions for easy workflow:
  - LaTeX object definitions correspond to HARK definitions
- Similar structure will be used for future contributions
  - Agent Archive Repository Deposit Vehicle for ARK?
- Instructions for cloning are in the README.txt
- You get the whole codebase under the Apache license
  - Basically, no limitations on use

- Of Get a GitHub account. Then, options to access are
  - Install GitHub Desktop App
  - Install 'git' command-line tool (if you're hard-core)
- 2 github.com/econ-ark/HARK is a "public repo"
  - Contains all existing code
- github.com/econ-ark/HARK/Documentation/NARK.pdf
  - Describes variable naming conventions for easy workflow:
  - LaTeX object definitions correspond to HARK definitions
- Similar structure will be used for future contributions
  - Agent Archive Repository Deposit Vehicle for ARK?
- Instructions for cloning are in the README.txt
- You get the whole codebase under the Apache license
  - Basically, no limitations on use
  - But, please credit us, and participate in discussions

## Who Has Produced It?

Name	TLA	Affiliation
Christopher D Carroll	CDC	JHU, CFPB
David C Low	DCL	CFPB
Nathan M Palmer	NMP	OFR
Matthew N White	MNW	UDel, CFPB
Alex Kaufman	AMK	$CFPB \to ? \; (Alcatraz?)$
Jiaxiong Yao	JXY	$JHU \to IMF$

Nothing herein may be interpreted as reflecing opinions of

CFPB - United States Consumer Financial Protection Bureau

JHU - Johns Hopkins University

IMF - International Monetary Fund

OFR - Office of Financial Research, U.S. Treasury

UDel - University of Delaware

Hired CDC as Chief Economist with this as a key priority

6 / 16

- Hired CDC as Chief Economist with this as a key priority
- Hired NMP as intern to get started

- Hired CDC as Chief Economist with this as a key priority
- Hired NMP as intern to get started
- Hired MNW as Visiting Scholar to work on it

- Hired CDC as Chief Economist with this as a key priority
- Hired NMP as intern to get started
- Hired MNW as Visiting Scholar to work on it
- Hired DCL as new economist last year

- Hired CDC as Chief Economist with this as a key priority
- Hired NMP as intern to get started
- Hired MNW as Visiting Scholar to work on it
- Hired DCL as new economist last year
- Hired AMK as RA

## Organization Going Forward

Standard Github tools, esp:

Issue Tracker: If You See Something, Say Something

**Topic Czars** 

Standard Github tools, esp:

Issue Tracker: If You See Something, Say Something

### **Topic Czars**

Gatekeeper for Contributions

Standard Github tools, esp:

Issue Tracker: If You See Something, Say Something

- Gatekeeper for Contributions
- Responsible for Setting Out Tests A Module Should Pass

Standard Github tools, esp:

Issue Tracker: If You See Something, Say Something

- Gatekeeper for Contributions
- Responsible for Setting Out Tests A Module Should Pass
  - e.g. Special Cases With Analytical Solutions

Standard Github tools, esp:

Issue Tracker: If You See Something, Say Something

- Gatekeeper for Contributions
- Responsible for Setting Out Tests A Module Should Pass
  - e.g. Special Cases With Analytical Solutions
  - Metrics for "closeness" to "true" solution

Standard Github tools, esp:

Issue Tracker: If You See Something, Say Something

- Gatekeeper for Contributions
- Responsible for Setting Out Tests A Module Should Pass
  - e.g. Special Cases With Analytical Solutions
  - Metrics for "closeness" to "true" solution

Standard Github tools, esp:

Issue Tracker: If You See Something, Say Something

- Gatekeeper for Contributions
- Responsible for Setting Out Tests A Module Should Pass
  - e.g. Special Cases With Analytical Solutions
  - Metrics for "closeness" to "true" solution

Name	Topic	Affiliation
Serguei Maliar	Interpolation	Stanford
Lilia Maliar	Interpolation	Stanford
We're Seeking Volunteers for Czars		

Standard Github tools, esp:

Issue Tracker: If You See Something, Say Something

- Gatekeeper for Contributions
- Responsible for Setting Out Tests A Module Should Pass
  - e.g. Special Cases With Analytical Solutions
  - Metrics for "closeness" to "true" solution

Name	Topic	Affiliation
Serguei Maliar	Interpolation	Stanford
Lilia Maliar	Interpolation	Stanford
We're Seeking Volunteers for Czars		

- info@econ-ark.org -
- General Purpose Questions
- czars@econ-ark.org Volunteer to be a Czar
- ideas@econ-ark.org -Ideas for Improvement

When	What	Lessons
2006-2013	SolvingMicroDSOPs	Surprisingly popular
2014-12	IMF-CFPB Workshop	Lots of enthusiasm
2015-12	CFPB-IMF Workshop	Not HARK, ARK!
		Testing, Replication, Feedback
2016-06	Hello!	None yet

• The version at http://github.com/econ-ark is our "public beta"

When	What	Lessons
2006-2013	SolvingMicroDSOPs	Surprisingly popular
2014-12	IMF-CFPB Workshop	Lots of enthusiasm
2015-12	CFPB-IMF Workshop	Not HARK, ARK!
		Testing, Replication, Feedback
2016-06	Hello!	None yet

- The version at http://github.com/econ-ark is our "public beta"
- So far as we know, everything works

When	What	Lessons
2006-2013	SolvingMicroDSOPs	Surprisingly popular
2014-12	IMF-CFPB Workshop	Lots of enthusiasm
2015-12	CFPB-IMF Workshop	Not HARK, ARK!
		Testing, Replication, Feedback
2016-06	Hello!	None yet

- The version at <a href="http://github.com/econ-ark">http://github.com/econ-ark</a> is our "public beta"
- So far as we know, everything works
- First non-beta: Built-in tests for everything

When	What	Lessons
2006-2013	SolvingMicroDSOPs	Surprisingly popular
2014-12	IMF-CFPB Workshop	Lots of enthusiasm
2015-12	CFPB-IMF Workshop	Not HARK, ARK!
		Testing, Replication, Feedback
2016-06	Hello!	None yet

- The version at <a href="http://github.com/econ-ark">http://github.com/econ-ark</a> is our "public beta"
- So far as we know, everything works
- First non-beta: Built-in tests for everything
  - Aim: This year

# Why Are Policy Institutions So Interested?

Participation: CFPB, OFR, IMF Interest From: FRB, ECB, BLS

• Policymaking = Applied Theory. Options:

# Why Are Policy Institutions So Interested?

Participation: CFPB, OFR, IMF Interest From: FRB, ECB, BLS

- Policymaking = Applied Theory. Options:
  - Informal, intuitive, "wetware" theory

# Why Are Policy Institutions So Interested?

Participation: CFPB, OFR, IMF Interest From: FRB, ECB, BLS

- Policymaking = Applied Theory. Options:
  - Informal, intuitive, "wetware" theory
  - Pormal, structural, "software" theory

'Local Average Treatment Effects' results are

• Not Even Very Empirically Relevant ...

- Not Even Very Empirically Relevant ...
- UNLESS used to estimate 'structural' parameters

- Not Even Very Empirically Relevant ...
- UNLESS used to estimate 'structural' parameters
- Because the important question is

- Not Even Very Empirically Relevant ...
- UNLESS used to estimate 'structural' parameters
- Because the important question is
  - What does world look like non-locally ...

- Not Even Very Empirically Relevant ...
- UNLESS used to estimate 'structural' parameters
- Because the important question is
  - What does world look like non-locally ...
  - ... = after the policy change

- Not Even Very Empirically Relevant ...
- UNLESS used to estimate 'structural' parameters
- Because the important question is
  - What does world look like non-locally ...
  - ... = *after* the policy change
  - and maybe not even just "on average"

- Not Even Very Empirically Relevant ...
- UNLESS used to estimate 'structural' parameters
- Because the important question is
  - What does world look like non-locally ...
  - ... = after the policy change
  - and maybe not even just "on average"
    - because distributional/targeted impact may be whole point

# Welfare Analysis With Heterogeneity

Sensible cost-benefit analysis requires:

Estimates of distribution of heterogeneous outcomes

# Welfare Analysis With Heterogeneity

Sensible cost-benefit analysis requires:

- Estimates of distribution of heterogeneous outcomes
- Utility or other weighting of those outcomes

# Welfare Analysis With Heterogeneity

#### Sensible cost-benefit analysis requires:

- Estimates of distribution of heterogeneous outcomes
- Utility or other weighting of those outcomes
- → Structure

Wrong explanations for the Scientific Revolution:

Invention of 'the experiment'

- Invention of 'the experiment'
- Invention of the printing press

- Invention of 'the experiment'
- Invention of the printing press
- ..

- Invention of 'the experiment'
- Invention of the printing press
- ..

Wrong explanations for the Scientific Revolution:

- Invention of 'the experiment'
- Invention of the printing press
- ...

### Right explanation:

Creation of community of scholars

Wrong explanations for the Scientific Revolution:

- Invention of 'the experiment'
- Invention of the printing press
- ...

#### Right explanation:

- Creation of community of scholars
- ... whose methods and results were 'open source'

Wrong explanations for the Scientific Revolution:

- Invention of 'the experiment'
- Invention of the printing press
- ...

#### Right explanation:

- Creation of community of scholars
- ... whose methods and results were 'open source'
- ... who critcized and improved and debugged each other

Wrong explanations for the Scientific Revolution:

- Invention of 'the experiment'
- Invention of the printing press
- ...

#### Right explanation:

- Creation of community of scholars
- ... whose methods and results were 'open source'
- ... who critcized and improved and debugged each other

Wrong explanations for the Scientific Revolution:

- Invention of 'the experiment'
- Invention of the printing press
- ...

#### Right explanation:

- Creation of community of scholars
- ... whose methods and results were 'open source'
- ... who critcized and improved and debugged each other

#### Alchemy → Chemistry

Wrong explanations for the Scientific Revolution:

- Invention of 'the experiment'
- Invention of the printing press
- ...

#### Right explanation:

- Creation of community of scholars
- ... whose methods and results were 'open source'
- ... who critcized and improved and debugged each other

### Alchemy $\rightarrow$ Chemistry

17th and 18th century version of github.com!

### Economists are People Too ...

• We are way behind many scientific fields in 'open source' code

- We are way behind many scientific fields in 'open source' code
- Surveys/Experiments: Economics students are more 'selfish.'

- We are way behind many scientific fields in 'open source' code
- Surveys/Experiments: Economics students are more 'selfish.'
- Options:

- We are way behind many scientific fields in 'open source' code
- Surveys/Experiments: Economics students are more 'selfish.'
- Options:

- We are way behind many scientific fields in 'open source' code
- Surveys/Experiments: Economics students are more 'selfish.'
- Options:
  - 'selfish' people study economics

- We are way behind many scientific fields in 'open source' code
- Surveys/Experiments: Economics students are more 'selfish.'
- Options:
  - 1 'selfish' people study economics
  - Studying economics makes you selfish!

- We are way behind many scientific fields in 'open source' code
- Surveys/Experiments: Economics students are more 'selfish.'
- Options:
  - 'selfish' people study economics
  - Studying economics makes you selfish!
  - Economics students are just more honest

- We are way behind many scientific fields in 'open source' code
- Surveys/Experiments: Economics students are more 'selfish.'
- Options:
  - 'selfish' people study economics
  - Studying economics makes you selfish!
  - Economics students are just more honest

- We are way behind many scientific fields in 'open source' code
- Surveys/Experiments: Economics students are more 'selfish.'
- Options:
  - 'selfish' people study economics
  - Studying economics makes you selfish!
  - Economics students are just more honest

I prefer (3)!

## Lessons Learned from Other Fields About What Works

Not taking the dewy-eyed view: "Build it and they will come"

## Lessons Learned from Other Fields About What Works

- Not taking the dewy-eyed view: "Build it and they will come"
- Emprical fact: Many other open source communities have succeeded

## Lessons Learned from Other Fields About What Works

- Not taking the dewy-eyed view: "Build it and they will come"
- Emprical fact: Many other open source communities have succeeded
- Economists can't be that different ...

Czars for specific topics

- Czars for specific topics
- Bounties for Best Solution of Specific Problems

- Czars for specific topics
- Bounties for Best Solution of Specific Problems
- Time-Stamped Public Mechanism for Staking a Claim to New Idea

- Czars for specific topics
- Bounties for Best Solution of Specific Problems
- Time-Stamped Public Mechanism for Staking a Claim to New Idea
- Stack-Exchange-Like Q&A Forum

- Czars for specific topics
- Bounties for Best Solution of Specific Problems
- Time-Stamped Public Mechanism for Staking a Claim to New Idea
- Stack-Exchange-Like Q&A Forum
- Mechanism for Easy Creation of Grad Student Problem Sets

- Czars for specific topics
- Bounties for Best Solution of Specific Problems
- Time-Stamped Public Mechanism for Staking a Claim to New Idea
- Stack-Exchange-Like Q&A Forum
- Mechanism for Easy Creation of Grad Student Problem Sets
- Tool for Grad Student Replication Exercises

- Czars for specific topics
- Bounties for Best Solution of Specific Problems
- Time-Stamped Public Mechanism for Staking a Claim to New Idea
- Stack-Exchange-Like Q&A Forum
- Mechanism for Easy Creation of Grad Student Problem Sets
- Tool for Grad Student Replication Exercises
- Eventually, a Journal?

- Czars for specific topics
- Bounties for Best Solution of Specific Problems
- Time-Stamped Public Mechanism for Staking a Claim to New Idea
- Stack-Exchange-Like Q&A Forum
- Mechanism for Easy Creation of Grad Student Problem Sets
- Tool for Grad Student Replication Exercises
- Eventually, a Journal?
- ... Your Ideas? ideas@econ-ark.org

#### Options:

subscribe@econ-ark.org

- subscribe@econ-ark.org
  - Add me to the newsletter/mailing list

- subscribe@econ-ark.org
  - Add me to the newsletter/mailing list
- Read the docs and slides and absorb what exists now. Options:

- subscribe@econ-ark.org
  - Add me to the newsletter/mailing list
- Read the docs and slides and absorb what exists now. Options:
  - Add an 'issue' that you want to tackle on github.com/econ-ark

- subscribe@econ-ark.org
  - Add me to the newsletter/mailing list
- Read the docs and slides and absorb what exists now. Options:
  - Add an 'issue' that you want to tackle on github.com/econ-ark
  - 2 letmehelpwith@econ-ark.org

- subscribe@econ-ark.org
  - Add me to the newsletter/mailing list
- Read the docs and slides and absorb what exists now. Options:
  - 4 Add an 'issue' that you want to tackle on github.com/econ-ark
  - 2 letmehelpwith@econ-ark.org
    - Of Define some area that you'd like to contribute to

- subscribe@econ-ark.org
  - Add me to the newsletter/mailing list
- Read the docs and slides and absorb what exists now. Options:
  - Add an 'issue' that you want to tackle on github.com/econ-ark
    - 2 letmehelpwith@econ-ark.org
      - 1 Define some area that you'd like to contribute to
      - email us at this address outlining what you propose to do

- subscribe@econ-ark.org
  - Add me to the newsletter/mailing list
- Read the docs and slides and absorb what exists now. Options:
  - Add an 'issue' that you want to tackle on github.com/econ-ark
  - 2 letmehelpwith@econ-ark.org
    - 1 Define some area that you'd like to contribute to
    - email us at this address outlining what you propose to do
    - We'll reply with some suggestions