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James:

When we last spoke in 2017, the newly founded Econ-ARK project had recently received a generous grant from the Alfred P. Sloan Foundation to develop the HARK toolkit, a software package for solving, simulating, and estimating heterogeneous agents models in economics (either heterogeneous agent macro or structural micro). With NumFocus as our fiscal sponsor, we have since received additional funding from other sources (including the Think Forward Initiative and T. Rowe Price as a "no strings attached" corporate sponsor) to continue the work and expand the range of models offered in the HARK package, allowing us to largely achieve our original set of goals. With this experience underneath our belt, we now see that our next steps involve developing a *language* for expressing dynamic structural models that can specify computational methods, describe simulation procedures, and generate model output. I am writing to you to ask whether Schmidt Futures might be interested in funding this endeavor.

To fix ideas, a structural model would be formalized as a model file: a set of statements characterizing its components, like how a budget constraint might be captured with a simple equation saying that assets are whatever is left of the consumer's money after consumption: `a=m-c` (of course much more sophisticated mathematical propositions would also be accommodated). The language (or perhaps a better term would be schema) will provide a common format for describing dynamic structural models convey model content in a human- and machine-readable way, but is independent of the code to actually solve and implement the model. As we develop the schema, we would simultaneously develop a software platform to parse the model file into the implied code.

The Dynare package provides a prototype example of the *kind* of thing we have in mind – but limitations in its syntax and specification mean that it cannot be used or extended for the kinds of models that are now *de rigeur* in both micro and macro modeling. When explaining our work on HARK, we have found that other economists often interpret it through the lens of Dynare, with the hope that we have already built "Dynare for heterogeneous agents." This has left us no doubt that there is a large demand for exactly such a tool. With our prior experience implementing `HARK`, and given recent advances in other software tools, we are now prepared to design and create it.

Prior to beginning work on the new platform, we conducted a thorough search of *other* academic fields, investigating whether a general dynamic modeling schema has already been developed. Having explored all the nooks and crannies of the internet, we are confident that there is no comparable or related project that could be adapted or expanded for our purposes. We found that the universe of modeling- and optimization-adjacent software is both diverse and diffuse: We found many of the building blocks necessary to accomplish our goal, but no schemes for putting the building blocks together into anything like what we need. The lack of a common platform for representing dynamic

models is akin to the lack of cohesion among the various artificial intelligence (AI) and deep learning toolkits that have recently been developed. Translated into that context, the AI equivalent would be a language that described the AI problem to be solved in a platform-independent way, allowing a user then to solve exactly the same model with each of the competing AI tools. (The problem is even more ambitious in that context than in ours, but what we accomplish might be a good stepping stone toward a platform-independent AI tool.)

This work will also significantly improve the transparency and replicability of structural economics research. Behind closed doors, everyone who works on these kinds of models admits (and laments) what they know to be true: Everyone's results depend on a host of ancillary assumptions – how many gridpoints to use, how many agents to simulate. While it is now expected that researchers will publicly archive their code, for many projects the code might as well be written in Klingon (so far as accessibility and transparency and replicability are concerned). Even worse, there is no direct relationship between the model as expressed *on paper* and the problem as solved *in code*– the academic refereeing system focuses deeply on the economics of the abstract math, and relies on trust with respect to the numerics. Indeed, there are famous examples of papers that have been published based on their strong economic content, but whose quantitative (and sometimes qualitative) results were later discovered to be based on errant code.

Our proposed modeling language aims to rectify these systemic issues with the workflow of economic research that uses dynamic structural models. If a model specification file is used to generate a numeric solution and model output, a reader or evaluator can be confident that the model presented on paper matches its execution in code. Furthermore, our language will include a format for specifying the methods used to solve the model numerically, transparently conveying this information alongside the "pure" mathematical content of the model. The software platform can thus act as a vehicle for evaluating the performance of a numeric solution to a theoretical model.

Our proposed platform will accelerate the development of models on the frontier of economic research, allow for the verifiability of numeric output from such models, and improve communication and collaboration among researchers. In addition to academic work, the platform would be of significant use both to governments (including central banks and financial regulators) in conducting prospective analyses of potential policy actions, and to private financial institutions who wish to make decisions or provide advice that is informed by a structural model (e.g. a model of optimal retirement savings). In developing the language and the software platform, we will seek out input from a variety stakeholders to ensure that their modeling needs are met.

Our sense is that, among potential funders, Schmidt Futures would be the best fit. The connection to Google and its engineers offers the hope that we might get excellent guidance about the many choices that lie ahead.

Sincerely,

Christopher D. Carroll, Professor of Economics, Johns Hopkins University