

Reply to Referee Report 1

Thank you for your comments, which helped us to clarify our argument and to address it to a wider audience. In the revised version of our paper, we included, e.g., more results on dynamics of the BC game in order to connect it better to the macroeconomic literature. In what follows, we reply in detail to your specific comments.

Comment:

p.1: “wins a prize”. In principle, there are two distinct possibilities. Either the prize is a fixed amount, regardless of the values chosen, or it is proportional to the actual choice. In both cases, with a factor < 1 , 0 is the unique equilibrium, but in the latter case, that equilibrium is disadvantageous for the players, as an equilibrium player gets a reward of 0. I assume that you consider the former version, but it should be useful to also discuss the latter.

Answer:

In our revised introduction, we try to make the rules of the original BC game (guessing game, Nagel 1995) clearer. Indeed, here we refer to a fixed prize. In variation 3 of section 3, we introduce distance payoffs, in which participants are paid according to the distance of their guesses from the target number (e.g. $2/3$ of the average of all chosen numbers). Your idea that prizes could be proportional to the guesses would be a design feature that is completely new in the BC literature. Thus, we think it would be misleading to introduce it in our review.

Comment:

All mathematical symbols should be written in italics.

Answer:

We changed this accordingly.

Comment:

Top of p.3: a repetition

Answer:

Thank you. We deleted the repetitive explanation on the Nash-equilibrium of the standard BC game being zero (which we address already in the Introduction). Instead, we summarize the rules of the standard BC game and directly apply the level k model. We added a short note how level k thinking corresponds to finding the Nash-equilibrium.

Comment:

You switch between the symbols b and p without explanation. This was very confusing, but in the end I suspect that they mean the same.

Answer:

You are right: p and b mean the same. We decided to use p throughout the revised version of our paper.

Comment:

p.5: "We highlight ...": it seems that you are now back to b (or p) = $2/3$, but that should be said.

Answer:

Thank you, we clarified this.

Comment:

End of that paragraph is completely unclear. What, for instance, does $p = c + b$ mean?

Answer:

Thank you for this comment. Re-reading our discussion on Khaw et al. (2019), we came to the conclusion to delete it from our literature review on variations of the BC game.

Comment:

What is the point of surveying all the different variations anyway? You need to decide whether you want to give a survey of experimental beauty contests of the implications for macro. In the latter case, you should only present those variations that are relevant for that purpose. In the former case, leave out the macro discussion.

Answer:

In section 3, we now focus on the variations of experimental beauty contests that yield, in our view, important implications for macro. Furthermore, we try to be clearer in describing the relevance of these variations for macroeconomic models.

Comment:

p.6: "from 30 years of experimental games": as I understand, the experiments started with Nagel (1995). This is < 30.

Answer:

We changed it into 25 years.

Comment:

Variation 5: You suddenly jump to macro, but you should explain the connection first.

Answer:

Thank you. In the revised version, we start the section with the connection between behavior in the BC game and macroeconomic problems before giving a macroeconomic example for which this connection is relevant.

Comment:

End of variation 6: completely unintelligible.

Answer:

We worked on this paragraph to make it better understandable and put it in our new

variation 7b.

Comment:

p. 11: Signal for what? Also, a signal is some information about an outside event, and therefore, choosing your own signal does not make any sense.

Answer:

In the revised version, we define ϵ_i as an individual idiosyncratic signal for the target number. Also, we replaced own signal by idiosyncratic signal.

Comment:

Beginning of 4.1: repetition

Answer:

Thank you. We deleted the repetition from the Introduction.

Comment:

p.12: "in the next section 4": there is no such section.

Answer:

We corrected the reference.

Comment:

Now comes the important equation (1), but with an incomplete explanation (and a typo). I suppose, although this is not said, that $\hat{E}^i$ is some expectation, but what expectation precisely? Also, now future values y_{t+1} enter. How are they to be understood? Expected values? This is really crucial, and so it must be very carefully explained.

Answer:

Thank you very much for this question. We clarified this in the revised version.

Comment:

All equations involving β are corrupted. It seems that you have defined a very strange latex symbol.

Answer:

We revised all equations involving β .

Comment:

What is the "output gap"?

Answer:

Thanks for this clarification question. The output gap is the difference between output in the New-Keynesian economy and output under flexible prices. We added this explanation in the text.

Comment:

In (4), it is unclear whether φ_π is a function or a constant (later, it becomes clear that it is a constant). Why does it carry the subscript π ?

Answer:

Thanks for this comment. Following Gali (2008), we use the subscript π to highlight that this constant captures the response of the central bank to inflation as opposed to any other economic variable. We clarified this in footnote 7. We also specifically wrote that φ_π is a constant in our revised version.

Comment:

(2)-(4) can easily be reduced to a single equation, for instance by first inserting (3) into (4) and then (4) into (2). In particular, p then drops out, and therefore, it is completely superfluous (and not explained anyway)

Answer:

With equations (2)-(4), we followed the presentation of New-Keynesian models in the literature that we cited at the beginning of section 4.3.1: Woodford (2003), Gali (2008), Walsh (2010), Branch and McGough (2009).

Comment:

End of 4.2.2: "thus an choices"?

Answer:

We deleted "an".

Comment:

Beginning of 4.2.3: repetition

Answer:

We deleted this repetition in our new section 4.3.3.

Comment:

I am not an expert on the beauty contest, but I suppose the paper is addressed to readers like me. But then, the argument must be much more carefully presented. First of all, the basic form of the beauty contest is a one shot game, but in the end you are interested in macro problems where future expectations play a role. The connection is not completely obvious, but conceptually, this is a major step.

Answer:

Thank you. We hope that our revised version is clearer on that. We added more insights on dynamics in beauty contest experiments with more than just one round (Figure 2) in order to connect it better to macro problems. We also added more experiments on dynamics, i.e. with repeated interactions: in total we have now: 1. original Keynes Beauty contest (BC), 2. variation 1b (Nagel, 1995), with figure 2. Variation 4, Grosskopf Nagel with 2 person game. Variations 7b (strategic substitutes and complements. Variation 8 with unknown parameter specification.

Comment:

And then, the crucial argument why level k thinking is also relevant for understanding macro phenomena must be worked out. After all, it could simply be that for human market participants, the macro dynamics is so complicated that they revert to simple rules of thumb, instead of doing level 2 or 3 reasoning. What value of k would be chosen anyway in real market situations according to your theory?

Answer:

Inspired by your comment, we elaborated on the caveats of level k models in making predictions at the end of section 3. Since the average level k is quite stable between level 0 and 3, such average changes can be easily incorporated into behavioral models. We show in the different variations why there is typically no increase of level k . One is that the reference point changes and then subjects iterate with lower or higher levels according to their experience (see variation 1b). More important, levels don't change because most subjects think that others don't change their levels. This becomes self-fulfilling.

Reply to Referee Report 2

Comment:

This is a very nice review of beauty contest games and their application to New Keynesian models, but two leading experts in the field. I only have one very minor point. Figure 4, referring to the Heemeijer et al. (2009) experiments has no description/reference in the text, or at least, I could not find one. So that should be added somewhere.

Answer:

Thank you very much for your very positive feedback! We added the description of the Figure referring to Heemeijer et al. (2009) in variation 7b (Figure 5 in the revised manuscript).

Reply to Referee Report 3

Comment:

The paper is a nice review of k -level thinking and its applications to macroeconomics. It reviews all relevant advances in the experimental literature since the seminal work of Nagel (1995) and discusses recent application to macroeconomics.

Answer:

Thank you very much for your positive feedback!

Comment:

For macroeconomists the recent advances with k -level thinking, the description of out-of-equilibrium behavior in the introduction may be misunderstood (one could claim that in a repeated interaction

environment level k is at least a temporary equilibrium if not an equilibrium). What I'm asking for is just to define an environment in which this is an out of equilibrium behavior, so there is no confusion.

Answer:

We have now, in the introduction added the following paragraph in the introduction:

In response to the increasing use of non-rational expectations in economics, macroeconomic papers such as Woodford (2013) and Garcia-Schmidt and Woodford (2019) make use of the notion of temporary equilibrium. By temporary equilibrium they mean that market outcomes at any point in time result from optimizing decisions by households and firms but that their expectations need not be correct. Yet, since the predominant solution concept in macroeconomics is still the rational expectations equilibrium and human behavior (sometimes) converges to it, we take REE as the benchmark for our further exposition. Level k is one specification of non-rational expectations together with an iterated best reply structure. However, in the microeconomic literature, it has not been referred to as equilibrium choices, as beliefs and resulting best replies of different players are not consistent to each other.

Comment:

Perhaps you can briefly review also Angeletos and Huo (2019) paper (Myopia and Anchoring) in section 5.

Answer:

Thank you for this comment. We added a review on Angeletos and Huo (2019) in section 5.2.

Comment:

Perhaps you could omit some repetitions. For example, first paragraph of section 4.2.3 is a repetition of what was explained in the second paragraph on page 10.

Answer:

We went through the whole manuscript and deleted unnecessary repetitions.

Comment:

a few small typos:

- page 3: punctuation after the footnote call should be moved to the footnote (where parentheses have to be adjusted as well)
- page 13, third paragraph: replace "there" with "their."
- page 17: last sentence of paragraph3 is missing something, perhaps "be."
- page 18: spacing before call for footnote 5.

Answer:

Thank you! We copy-edited the whole manuscript and also corrected the typos you mentioned.

Reply to Referee Report 4

Comment:

The authors review the literature on level-k thinking with a particular focus on recent applications in behavioral macroeconomics. This paper could become a useful guide in light of a growing interest among macroeconomists in this deviation from the rational expectations assumption.

Answer:

Thank you for your positive feedback!

Comment:

There are three virtually identical paragraphs found in two different places in the paper (on pages 10 and 15).

Answer:

Thank you. We deleted the repetition.

Comment:

The following text does not seem to logically belong to Section 4 (it probably teleported there from Section 3, but I am not sure). The authors refer to Figure 6. However, there are only four figures in the paper.

Answer:

We deleted the paragraphs you mentioned in section 4.

Comment:

This is a review paper. I would very much appreciate not just the description of the old and new research but a more critical evaluation of this whole literature: limitations of level-k thinking, alternatives to level-k thinking, potential future directions of research, etc. Let me expand by giving a few examples.

- (a) It is well known that the outcome of level-k thinking depends crucially on level-0 behavior. This has been known for more than 20 years. Are there lessons from behavioral game theory for macroeconomics?

Answer: Within each variation in section 3 on BC experiments we make a link to the macro insides, especially with level 0 specifications. At the end of section 3, we now discuss the limits and virtues of level k models in making predictions and also summarize the experiments for macroeconomic interest.,

- (b) While level-k thinking is becoming popular in macroeconomics, it is far from being clear that it is very different from, for example, the dispersed information assumption (Angeletos and Lian, 2016; Angeletos and Huo, 2018). It would be very informative if the authors discussed the pros

and cons of these approaches in detail. Why should macroeconomists prefer level-k thinking over the dispersed information assumption?

Answer: In section 4 and 5 we discuss the works of Angeletos and Lian (2016), Angeletos and Huo (2018), and Coibion et al. (2018); we also add a paper by Gabaix (2019) with a link to the BC functions and level k literature.

(c) Level-k thinking has a lot of support in lab experiments. However, it is far from obvious that people outside of lab experiments behave in a similar way. I think there is a huge unanswered question of whether there is any evidence of level-k thinking in macro settings. One problem is that there is almost no data on higher-order beliefs in macro settings (Coibion, Gorodnichenko, Kumar, and Rynngaert, 2018 is one exception). I think a discussion along these lines can be very illuminating.

Answer: In the conclusion we raise the point that there are not many empirical papers on level k in the macroeconomics literature besides the paper you mention, which we also discuss in section 5.

We write the following paragraph about future research directions.

Possible directions of future research regarding bounded rationality in macroeconomics could be the following: First, there is potential for more empirical work regarding level k and higher-order beliefs in real world macroeconomic settings, using data from surveys, field experiments, and professional forecasters. Second, level k is certainly not the only alternative to the growing field of behavioral macroeconomics. While learning models, for example, have long ago been built into macroeconomic theories (see Evans and Honkapohja, 2001), there have been other experimentally founded models such as the heuristic-switching model with heterogeneous expectations by Brock and Hommes (1997) and Anufriev and Hommes (2012). Hommes and Lustenhouwer (2019) use this model to analyze inflation targeting and central bank credibility. Yet, there is certainly more potential for this model to be used in macroeconomic theory. Third, given the initial success of using level k - a model from the experimental literature - in macroeconomics, more collaboration between macroeconomic theorists and experimentalists could be fruitful. Events such as the “BESLab Experimental Economics Summer School in Macroeconomics” were set up to educate young macroeconomic researchers in experimental methods.

Thank you very much for these helpful comments!