Report on Oxford MPhil thesis 2019 "Dispersion of the temperature exposure and economic growth: panel evidence with implications for global inequality" by Matthew Davis

This ambitious thesis carefully uses historical data on daily temperature anomalies to re-examine the within-country effect of aggregate temperature on economic productivity in different parts of the world by allowing for higher-order moments of temperature exposure. It estimates for this purpose a fixed-effects panel regression model. The estimates are subsequently applied to exogenous scenarios of future socio-economic and climatic conditions to assess the welfare effects of projected climate change by the end of this century. The findings are that rich and cold countries are largely insulated from or are beneficiaries from climate change, but poor and hot countries suffer on balance adverse welfare effects from climate change. The findings imply that higher levels of global warming leads to increasingly unequal distributions of global GDP.

This thesis advances on earlier pioneering econometric work on the same topic by Dell, Jones and Olken (2012) and especially by Burke, Hsiang and Miguel (2015), who were the first to move away from specifying fairly ad-hoc (and typically global rather than region-specific) damage functions as is prevalent in the literature based on integrated assessment models (IAM) to properly estimating the nonlinear (quadratic) effects of temperature (and precipitation) on the economies of different part of the planet. The innovation in this thesis is to not only use mean annual temperature as a sufficient statistic for temperature exposure at the aggregate level, but also use the interaction effect with the standard deviation of daily temperatures over the course of a given year on economic outcomes. The novelty is thus to take account of the dynamic growth effects of dispersion in temperature exposure when deriving a comprehensive temporal aggregation of temperature. This makes eminent sense and has to my knowledge not been done before. The results in this thesis are thus of wider interest. A shorter version makes a good chance of being published at a very good journal.

Dell et al. find negative effects on growth rates for developing countries (i.e. a 1.3%-point lower for each degree Celsius increase in mean temperature), but not for developed countries. This thesis finds similar results: by 2099 the effect on the growth rate of poor countries will be between -4.2%-points and +0.7%-points relative to the counterfactual without climate change. The 90% confidence interval is [-1.0, +2.2] %-points for rich countries. Interestingly from a policy perspective, by 2099 the poor are expected to see a 62-90% drop in GDP per capita relative to the scenario without further warming. In the most extreme warming scenarios there is a rapid convergence between countries' ordinal GDP per capita rankings and mean temperature rankings. The thesis therefore refers to a "temperature trap" for developing countries, so that not fighting global warming seals the fate of the poorest countries on the planet. These are very striking results with direct policy relevance, and I am impressed to see them so well done in a thesis.

The opening pages offer a clear introduction, but it would be nice to give some motivating examples right up front of why volatility of temperature over the course of a year matters. Section 1.1 gives a fair critique of existing ad-hoc damages estimates in the IAM literature, and rightly sides with the devastating critique of Pindyck. There is a very recent meta-survey by Nordhaus and Moffat, which criticises and corrects the meta-survey done by Tol in his JEcPersp article. It might have been nice to discuss the more convex and even more ad hoc specifications put forward by Ackerman and Stanton and by Weitzman. Convexity of damages plays little role in the thesis, but it deserves some discussion. More generally, this subsection does not discuss uncertainty ranges of damage ratio estimates even though they have been used in the IAM literature (e.g. by Traeger). Section 1.2 briefly surveys the genuinely empirical estimates of global warming on a range of socio-economic outcomes and argues why it may be better to use a Ricardian approach via hedonic regressions to overcome the "dumb farmer" bias or not as explained by Deschenes and Greenstone (2017). The latter therefore propose a fixed effects panel regression instead of the hedonic cross-section model. This subsection is excellent and very informative. The globally nonlinear response function relating growth in output to temperature, temperature squared, etc., i.e. (6) of Burke et al. (2015) leads to a globally optimal temperature of 13 degrees Celsius. Section 1.3 points out that weather variability during a year is important too, which motivates putting higher-order moments of temperature exposure in (6) too. It points out that the US and Peru have similar mean temperatures, but whereas Peru has stable temperatures throughout the year the US has a lot of temperature variabilities during the different seasons and might suffer therefore more from climate change even though mean temperatures are roughly the same in the two countries. It would be nice to discuss in this sub-section whether deaths rise more after a very hot summer, or that they are simply brought forward a few weeks or months. Finally, section 1.4 makes the case for differential impact and inequality.

Section 2 sets out the framework of the thesis. Subsection 2.1 gives some nice theory motivating the final regression equation to be used. Although the thesis could be read without going in the full details of this material, I enjoyed it as it clarified some issues in my mind to do with the effects of mean-preserving spreads (see Proposition 1 and Figure 4). Most readers will jump immediately to subsection 2.2 and the regression equation (18). It would have been helpful to explain even more carefully why the theory in subsection 2.1 implies an equation like (18). Section 2.3 explains how welfare implications are derived from (18) for the different RCP scenarios (giving mean and standard deviations of temperature) portrayed in Figure 6. Section 2.4 discusses the data.

The core results are then presented in subsection 3.1. The panel regression results with fixed effects reported in Table 1 and portrayed in the very useful Figure 7. The novel features in this regression are the new variables for temperature and temperature squared interacted with the standard deviation of temperature over the course of a year. A bootstrapping strategy is used to compute standard errors of the implied response functions. I would have liked to see a more robustness results with respect to functional forms and other factors for Table 1, and probably this would be required before submitting for publication. Section 3.2 and 3.3 use the estimated results to investigate the implications for global GDP per capita and international inequality (Lorenz curves and Ginis), respectively. Section 4 concludes and suggests some areas for further research.

I conclude with a critical comment regarding the methodology and a suggestion. Much in the exercise is kept exogenous, when obviously economies and people will adapt to climate change. The exercise uses the various RCP scenarios and thus abstracts from any behavioural responses. In a sense, a better case can be made why this thesis is not susceptible to the "dumb farmer" assumption discussed in the literature. For example, the excellent work of Esteban Rossi-Hansberg could have been discussed. He finds that, once proper account is taken of migration from hotter to cooler places in response to global warming, the negative effects of climate change are much weaker. His work uses evidence on coastal flooding and spatial shifts over the last 200 years, so may not immediately fit within the thesis. But some discussion of adaptation forces would have been useful.

My final suggestion is to give a better guide to the reader who normally uses integrated assessment models what tractable structural damage function they should use when maximising welfare and deriving optimal climate policy. Some sense of how results would differ compared to using the Nordhaus or Stern-Weitzman style damage functions would be very helpful. The reader suspects that damages to GDP or the rate of GDP derived in this thesis be much higher and will lead to much more ambitious climate policy. Some discussion of whether policy makers can make do with a global IAM like DICE or should use regionally disaggregated IAMs would be helpful too.