Response to Reviewer 1

We thank Reviewer 1 for raising several points that led to clarifications, particularly those requested to reach a broader audience in the economics community. We agree with the reviewer that the impacts of climate change on prices and inflation are less developed than the impacts on real output. This gap is precisely the motivation for the paper.

The review appears to evaluate the manuscript mainly against the expectations of a conventional monetary or regional price-level model. Our manuscript approaches the problem from a different angle, deliberately focusing on a highly aggregated global framework in which inflation emerges from the widening gap between nominal and real production, with real production defined in terms of inflation-adjusted output and its historical accumulation into the quantity we call Wealth. The core definition is

$$W(t) = \int_0^t Y(u)\, du,$$

where Y is real, inflation-adjusted global output. Wealth, as it is defined is derived from standard economic quantities but despite its simplicity is not a standard economic quantity. What we show is that introduction of this quantity confers a number of simplifications in the analytical treatment that lead to a compact definition of inflation that has not been previously described. We further show that this new economic definition can be directly linked to important physical quantities related to primary energy consumption and civilization material growth. The approach is central to the paper while distinct from standard monetary models of regional price determination.

Nevertheless, we have made significant revisions to the manuscript to make the scope clearer, especially insofar as how the approach we describe not only differs from more tradiational approaches but is in fact qutie complementary. We also explain more explicitly why long-run inflation is relevant in the context of climate damages, investment, and the interpretation of IAM results. Section 2 is substantially rewritten, and the discussion sections make more explicitly clear how our theory differs from prior theories and why.

Addressing Reviewer 1's specific points:

- **"Any reasonable discussion of the determinants of the price level (money, fiscal theory of the price level, etc)."**

  We agree that money, fiscal policy, and monetary policy are central to many theories of price-level determination, especially at national or regional scales. Our paper does not attempt to replace those approaches. Rather, it addresses a different and more aggregated question: whether global climate damages can be related to inflation through the changing relationship between nominal and real global output.

  However, we take the Reviewer's point serious and have now added text to the Introduction and Discussion clarifying that the framework is not a theory of monetary transmission, nor a model of central-bank policy. Instead, it is a global accounting and physical-scaling framework in which inflation is interpreted as the rate of change of the wedge between nominal and real output. The relevant point for IAMs is that climate damages are usually applied to real GDP, whereas the inflationary response is left unspecified. Our contribution is to provide a theoretical route from climate-induced decay of accumulated Wealth to the gap between nominal and real GDP.

  The Introduction now includes the text

  > The goal here is to develop a very simple IAM that permits "back-of-the-envelope" analytical calculations of the forces driving future inflation and their relationship with the global-scale climate-damage function D. The new framework we introduce is not intended to substitute for monetary, fiscal, or regional theories of price-level determination, or to address the important problem of the impact of weather extremes on, e.g., the price of food, energy, housing, insurance, goods, and transport. Nor does it address how the inflationary consequences of climate shocks depend on both supply and demand on more regional and sectoral scales.

- **"Why long-run changes in the price level matter in aggregate in an economic sense. I'd agree entirely that short-run unexpected changes in prices can have welfare implications, but the model proposed does not include mechanisms that can shed any light on that. Why should we diverge from a standard model of utility being the discounted sum of real consumption (less disutility from labour). I could be open to an argument, if one were actually made."**

We agree that, in standard models, a fully anticipated proportional short-term change in the price level need not have first-order welfare effects. This assumes that all nominal quantities adjust perfectly. Our concern is complementary but different, as it discusses long-term climate-related inflation as a symptom of a growing diversion of economic activity away from net civilization expansion and toward maintenance, repair, and replacement of previously accumulated Wealth.

Consideration of inflation over long timescales is relevant because climate change is a long timescale phenomenon, and should it take place it has the potential to affect such important economic froces as long-term investment, intergenerational planning, and even the simple measurement of real economic growth. The concern we address is not simply that prices are higher, but also that rising prices may reflect a declining ability of civilization to add to real accumulated Wealth. We have revised the manuscript to clarify this point:

> In a more smoothly varying model of inflation that assumes frictionless adjustment, as is standard, changes in nominal prices do not necessarily reduce welfare. Our approach differs by addressing how inflationary shocks can be linked to an accelerating redirection of nominal economic activity from net expansion towards maintenance and repair. While this lies beyond the immediate scope of this paper, such a redirection might reasonably be expected to impact such fundamental economic aspects as how wealth is distributed, long-term investments, and the measurement of real growth. Damages to previously constructed networks from climate change, or any other force that constricts economic output, may emerge as rising prices but reflect a deeper underlying problem – a diminishing capacity of civilization to generate a net real addition to its accumulated productive infrastructure. As repair consumes the bulk of new production, inflation sky-rockets.

– **"No discussion of relative price changes versus inflation. Similarly no view on the role of monetary policy."**

We also now clarify that monetary policy may influence the timing, distribution, and measured expression of inflation, especially within national economies. However, monetary policy cannot by itself remove the underlying physical requirement that existing infrastructure, institutions, and networks must be maintained against decay. In our framework, the relevant global mechanism is not money creation per se, but the increasing fraction of nominal activity required to offset decay rather than to generate net real expansion.

> Our approach does not preclude monetary policy for controlling the short-run timing and magnitude of inflation, especially nationally. Rather what we address are the more fundamental underlying forces such as climate change that act as inflationary pressures over the long-run and at global scales, those that turn a growing share of nominal output towards merely maintaining or replacing previously constructed Wealth. Monetary policy may change how such a pressure is allocated internally, among countries, or between e.g. wages, debts, and the prices of goods. It cannot however erase the physical destruction of previously built networks or reduced access to resources of energy and raw materials. As $J \to 1$, the scope for monetary policy to offset physical constraints, without creating severe distributional consequences, may become increasingly limited.

– **"No attempt to motivate how wealth actually matters for output, or how changes in wealth change production."**

This seems to be a confusion about terminology. Our paper defines Wealth as the quantity $W(t)$ introduced above, and we capitalized the word throughout to remind the reader that it refers to this specific definition. We are aware that different definitions of wealth exist in the economic literature, for example as the "net worth" (i.e., the difference between assets and liabilities) of an individual, with corresponding investigation of how wealth relates to output, or how changes in wealth change production, but this is not how we use the term.

To recap, the manuscript defines Wealth as the historical accumulation of real output, so that $dW/dt = Y$, and then writes real output as $Y = \eta W$, where η has dimensions of inverse time. Thus, output is not introduced independently of Wealth; it is the rate at which the accumulated structure of civilization enables further real production.

This is intentionally broader than produced capital in a Cobb-Douglas production function. Wealth includes the cumulative physical, institutional, technological, cultural, and organizational structures that permit current production. The manuscript gives examples such as language, records, infrastructure, and accumulated sociocultural knowledge.

– **"No discussion of the decoupling of GDP growth and energy."**

We have added discussion of this point. The manuscript does not assume a fixed proportionality between annual GDP and annual primary energy consumption. Indeed, the paper explicitly distinguishes the commonly discussed correlation between Y and E from the empirical scaling between historically cumulative Wealth W and primary energy consumption E. The relevant relationship in our framework is not that GDP and energy use must grow one-for-one, but that accumulated Wealth is empirically tethered to the rate of energy consumption.

A further important implication of constant $\bar{w}$ can be seen by comparing Eq. 18 with Eq. 44, namely that:

$$\frac{d\ln Y}{dt} = \eta_E + \frac{d\ln \eta}{dt} \tag{1}$$

Long-term growth in global economic output (the left hand side of the equation) is driven not just by growth in energy consumption (the first term on the RHS) but the growth rate of the growth rate (the second term). If the second term is non-zero, then Y and E can become decoupled.

The problem starts with equation 7. The substitution of nominal GDP for real here is incorrect without a view on the role of the price level on wealth. The outstanding stock of wealth is revalued by changes to the price level and reduced by depreciation.

The reviewer writes that the problem starts with Eq. 7 and that nominal GDP has been incorrectly substituted for real GDP. We believe this reflects a misunderstanding of the definitions in the manuscript. There is no substitution of nominal GDP for real GDP. Rather, Eq. 7 follows from the definition of W and from the definition of the decay rate γ.

The manuscript first defines

$$\frac{dW}{dt} = Y,$$

where Y is real, inflation-adjusted output. It then rewrites this same identity as

$$\frac{dW}{dt} = Y_N - \gamma W,$$

with

$$\gamma = \frac{Y_N - Y}{W}.$$

Thus Eq. 7 does not assume that nominal GDP is real GDP. It defines the term γW as the difference between nominal output and the real addition to Wealth. In this sense, Eq. 7 is precisely the revaluation or decay term that the reviewer requests: it is the term that prevents nominal output from being integrated directly into real Wealth.

We have however, made substation clarification in Section 2 that clarify how these terms are calculated using standard economic quantities in a manner that is consistent with standard economic treatments.

This error leads to a view of stagflation. Yet over the long run of human history, the price level and output are positively correlated. In the short-term, growth and inflation are also positively correlated as well. There are a few, isolated, incidents of stagflation due to negative supply shocks. Here there is much more interest in terms of climate. Indeed, the bulk of the literature on the inflation impacts of extreme weather events find higher food prices. But lower wealth also reduces demand, and there are many well-known papers in that literature that point to the balance of supply versus demand being important in determining overall inflation impacts. None of those papers are cited or discussed in the present paper.

The reviewer argues that the alleged error leads to an incorrect view of stagflation and notes that output and the price level are often positively correlated. We do not disagree: historically, nominal output and prices can indeed rise together, and that short-run inflation may accompany periods of growth. Our argument is certainly not that inflation always implies contraction. Instead, our study is focused on a particular limiting case whereby climate damages or other stresses increase the fraction of nominal output that must be devoted to maintenance and repair simply to maintain real growth. Or alternatively that real growth may fall even as nominal growth continues.

In the notation of the manuscript, the relevant quantity is the wedge

$$J = \frac{\gamma}{\beta}.$$

As $J \to 1$, the net growth rate $\eta = \beta - \gamma$ tends toward zero. In that limit, nominal output may remain large because resources are still circulating through the economy, but real additions to Wealth become small. This is the limit in which stagflation emerges. It is not assumed. Rather it follows from the limiting behavior of the relationship between nominal production, decay, and real accumulation.

We have added discussion to clarify this point

> Thus, the model does not imply that inflation and output are always negatively correlated. During many historical periods of stagflation, nominal output, real output, and prices rise together. Stagflation is consistent with Eq. 22 for the limiting case that $J = \gamma/\beta \to 1$. In that limit, $\eta = \beta - \gamma \to 0$, which means that real growth rate of global Wealth approaches zero even as nominal flows of output remain positive. Stagflation emerges when increasing decay or declining production efficiency force nominal productivity to become increasingly absorbed by maintenance and replacement rather than net real expansion.

Notation

We thank the reviewer for the suggestion regarding notation. We now use instead of the symbol π for the damage function the symbol D.