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Hurry or Wait – The Pros and Cons of Going Fast or Slow on Climate Change

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Abstract: Climate change risk will likely force the de-carbonization of our electricity sector and thus involve massive investments in long-lived assets using many new and emerging technologies. Since technological progress (independent or dependent on deployment) will likely lower the future cost of those technologies, investing early and rapidly forecloses saving money by installing those technologies at a lower cost later. There are thus benefits to waiting until the costs of renewables fall further. However, there are also costs to waiting. First, given the longevity of greenhouse gases in the atmosphere, cumulative emissions matter and lowering greenhouse gas emissions earlier is beneficial. Second, there is significant uncertainty not only over the rate of change of the cost of low carbon technologies, but also over the cost of greenhouse gas emissions. The costs of waiting are complex in that the distributions themselves are unknown (and quite possibly have "fat" tails). There may also be complex timing issues such as points of no return in terms of global greenhouse gas concentrations, beyond which the costs of adapting to climate change effects become essentially infinite. Hurrying can therefore be considered an insurance policy against the unknown but perhaps increasing risk of catastrophic damage.

Keywords: climate change; electricity sector; environmental risks; fat tails; greenhouse gas emissions.

The risks associated with climate change are likely to force the de-carbonization of our electricity sector involving massive investments in long-lived assets using many new and emerging technologies. Given the rate of technological progress (independent or dependent on deployment) it is likely that the future cost of those

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technologies will reduce. Thus, investing early and rapidly, say by installing large amounts of solar photovoltaic (PV) today, forecloses saving money by installing lower cost PV on the same roofs later. As such, there are benefits to waiting until the costs of renewables reduce further. This is likely the case even recognizing that some portion of the decline in costs over time is related to experience gained from deploying the technology.

On the flip side, there are also costs to waiting. First, given the longevity of greenhouse gases in the atmosphere, cumulative emissions matter and lowering greenhouse gas emissions earlier is beneficial. Second, there is significant uncertainty surrounding both the rate of change of the cost of low carbon technologies, and also over the cost of greenhouse gas emissions.

The costs of waiting are complex in that the distributions themselves are unknown (and quite possibly have "fat" tails). There may also be complex timing issues such as points of no return in terms of global greenhouse gas concentrations, beyond which the costs of adapting to climate change effects become essentially infinite. Hurrying can therefore be considered an insurance policy against the unknown but perhaps increasing risk of catastrophic damage.

1 Hurry or Wait Framework

In summary, there are benefits to both waiting (option value) and hurrying (insurance value) on climate change mitigation: hurrying reduces the risks of catastrophic climate change, but could in theory be significantly more expensive than waiting.

We suggest that, given the uncertainties, it is likely preferable to err on the side of going too fast than too slow. To support that conclusion, we use a simple, back of the envelope calculation for the electricity sector in the United States to estimate how much money could be spent by hurrying, and how significant this potential outlay seems relative to the risk of waiting too long.

2 Back of the Envelope

In 2012 electricity production in the United States was a little more than 4000 TWh, of which approximately two-thirds was generated by fossil fuels, the remainder coming from nuclear, hydro and non-hydro renewables (EIA 2014a). Production is growing by about one percent per year and assuming this growth rate continues until 2040, annual production would be approximately 5400 TWh per year by 2040 (Faruqui and Shultz 2012).

Some of the existing power plants are old, others are newer, but we assume that by 2040 all of the existing capacity will need to be replaced with new plants. For resources entering service by 2019, the Energy Information Administration (2014b) estimates the average cost of power from fossil plants to be between $64 and $147/MWh (not accounting for the cost of greenhouse gas emissions), the cost of hydro to be $85/MWh, and the cost of renewables between $80/MWh (onshore wind) and $243/MWh (solar thermal). For our calculation, we assume a constant cost of $100/MWh for fossil generation, $85/MWh for hydro power, $100/MWh for nuclear and a current cost of a mix of renewable power of $150/MWh, declining to $100/MWh by 2040. Actual costs vary significantly by location and high levels of renewable power will likely require investments in additional resources to match the variable renewable generation with demand, but our estimate of $150/MWh likely includes room for significant such "integration" investments.

We consider two scenarios, wait versus hurry. In the "wait" scenario, we replace the entire stock of assets to meet energy demand of 5400 TWh through 2040 with the same mix we have today, i.e. 68 percent from fossil fuel generation, 7 percent from hydro generation, 19 percent from nuclear and 6 percent from renewables and delay deploying carbon-free resources until they reach cost parity with fossil generation in 2040. In the "hurry" scenario, we replace the entire stock of assets with 7 percent from hydro, 19 percent from nuclear and 74 percent from other renewables today.

At a real discount rate of 3 percent and with those assumptions, the present value of the additional cost of the "hurry" relative to the "wait" scenario would be $2.9 trillion or approximately 0.8 percent of US GDP through to 2040 (assuming a 1.5 percent per year annual growth rate), or 0.5 years of real growth (Bureau of Economic Analysis 2014).

We next consider the flip side: the value of hurrying/cost of waiting.

Current US fossil power plant CO_2 emissions are approximately 2 billion metric tons (about 0.5 tons per MWh of consumption). Assuming linear growth to 5400 TWh by 2040, average avoided GHG emissions under the hurry versus wait scenario would be 2.4 billion metric tons of CO_2 per year.

Estimates of the social cost of carbon (SCC), although complex and hence not uncontroversial, allow valuation of the economic cost of CO_2 emissions. Estimates of the SCC vary widely and are highly sensitive to the chosen discount rate and year. The US Interagency Working Group on the Social Cost of Carbon estimate SCC ranges from $22 to $92 per ton (in 2011 dollars) between now and 2040, corresponding to discount rates from 5 to 2.5 percent, respectively, with others (such as the Stern report) suggesting significantly higher values. These estimates imply a present value of the costs of waiting due to higher CO_2 emissions in the period 2015 – 2040 between $0.5 trillion to $5.7 trillion depending on the chosen discount rate, with $2.1 trillion using the medium discount rate of 3%.

Since both the rate of decline in renewables costs and the true social cost of carbon are highly uncertain, this back-of-the envelope analysis suggests that the costs ($2.9 trillion) and benefits ($2.1 trillion) of hurrying versus waiting are broadly comparable and that, based on the factors considered so far, society wouldn't make a very costly mistake either way.

3 Uncertainties and Fat Tails

The analysis so far makes one crucial assumption, namely that the *expected* impact of greenhouse gas emissions on our climate is a good guide for decision making. There is however significant evidence that this may not be the case. In particular, as discussed by Weitzman and others, the distribution of forecast temperature changes in response to increasing GHG emissions has "fat tails" (Weitzman 2009, 2011; Wagner and Weitzman 2015).

Concretely, while the expected effect of doubling CO_2 emission from about 350 PPM to 700 PPM is an increase in mean global temperatures of the order of 1.5–2.5 degrees Celsius, there is more than a ten percent chance that it will result in temperature increases in excess of 6°C.

There are no realistic estimates of the economic impacts of global temperature increases of 6°C or more over a geologically very short time period, but they would likely be catastrophic. The range of estimates of the social cost of carbon does not account for this "fat tails" risk.

In theory, a non-trivial risk of infinitely costly consequences of climate change would of course suggest that reducing greenhouse gas emissions now at any cost would be optimal, no matter how those future (infinite) costs are discounted to the present. In practice, it suggests that if the costs and benefits of hurrying and waiting are broadly comparable before considering fat tail risk, the fat tail risk is likely orders of magnitude different and would thus provide a strong rationale for hurrying.

4 Bringing it all Together

As we have discussed, the types of uncertainty associated with hurrying or waiting are quite different. Uncertainty about the rates with which the cost of new technologies will decline can be estimated with reasonable confidence using empirical data, even though each technology is different and estimated cost declines only apply to existing technologies (and hence ignore the possibility of revolutionary new inventions). At any rate, while uncertain, these costs are bounded from above by the cost of currently available technology and below by zero.

In fact our simple analysis likely overstates the cost of hurrying, since we assume that the switch to a carbon free electricity sector would occur overnight. In reality, supply chains for renewable energy and the necessary complementary investments in infrastructure (not to speak of regulatory rules, etc.) take time, so that a more realistic version of the "hurry" scenario would be to ramp up the transition over some time, perhaps along a path similar to those pursued by some of the more aggressive countries such as Germany. The German experience shows that it is indeed possible to pay significantly more for renewable energy by deploying early. However, it also shows that the cost of transitioning to a renewable electricity system declines over time, at least partially helped by the commitment to rapid deployment itself.

The second area of uncertainty concerns the costs of greenhouse gas emissions and the chosen discount rate. There is much debate surrounding the appropriate level of discount rate and whether it should be constant or decreasing into the future. As the analysis above shows, the difference in capital costs between the wait and hurry scenarios is $2.9 trillion before any carbon costs are considered. Thus, in the absence of any cost of carbon, this uncertainty surrounding discount rates and greenhouse gas emissions costs could also be considered as bounded from above by $2.9 trillion (representing a highly conservative carbon cost of zero).

The third area of uncertainty is related to fat-tails. Our simple analysis shows that the costs of deploying renewable energy as quickly as we can are comparable to the benefits of lowering greenhouse gas emissions more rapidly, assuming that our expectations about the change in temperature in response to increasing greenhouse gas emissions are correct. However, there is a chance that those expectations are incorrect and that actual temperature increases will be far more serious, with a ten percent or higher risk of catastrophic economic effects. This third uncertainty, unbounded and with non-trivial probability, significantly tips the balance in favor of hurrying.

We therefore conclude that even though policy makers should be well aware of the trade-off between going fast and going slow, the benefits of waiting are likely insufficient to justify delaying rapid de-carbonization, in light of the significant risks associated with waiting. If the extra cost of deploying renewables early is seen as insurance against the unknown, but considerable risk of climate change being a much more severe or urgent problem, the associated premium seems reasonable if not cheap. Borrowing a recently used analogy, if you knew that passing a car in a bend without visibility will save you 5 seconds to get to your destination, would you pass if you knew there was a 10% chance of being killed by facing an unexpected oncoming car?

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