Impact of Climate Change on TFP Growth

Term Paper

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This empirical paper examines the impact of climate change (measured using temperature and precipitation normals) on Total Factor Productivity (TFP) growth. In Solow's model, TFP is a key determinant of growth besides traditional inputs of labour and capital. Thus, to know whether climate change will impede growth through negative effects on TFP, it is of interest to economists to understand the impact of climate change on TFP growth. Moreover, as Letta and Tol (2019) have argued, if climate change were to negatively affect TFP, there is a case to be made for higher carbon taxes. The consensus in the existing literature is that the impact of climate on TFP is negative, but small. This paper uses a cross-country panel dataset of 116 countries by subsets of poor/non-poor countries and hot/non-hot countries. The finding is that countries that are both hot and poor experience a statistically significant reduction of 1.36 percent in TFP growth with a degree rise in temperature. This number is much larger than the estimate of Letta and Tol (2019) and has serious implications for the economic growth of developing countries.

Introduction

Total Factor Productivity represents a combination of productivity of labour and productivity of capital, which accounts for increases in total output that are not due to labour or capital inputs (Letta & Tol, 2019). In other words, TFP is a rough measure of technological progress. This has two implications. Firstly, it becomes important for development economists to understand the extent to which climate change impedes the process of development because the negative impact of climate on TFP growth will ultimately affect GDP growth (simplistically, growth can be taken as a proxy for economic development). Further, existing climate models assume that the effect of climate change on TFP is negligible. If climate change harms TFP growth, impact estimates in these models will get revised. Letta and Tol (2019) suggest that the social cost of carbon could increase in such a situation.

Oritz-Bobea et al. (2021) find that there is wide cross-country variation in the growth of agricultural TFP over the years. It is intuitive that climate change impacts will be felt differently by different geographies, and by the affluence of the countries.The differential effects may arise because affluent countries can better adapt to changed climate or because they have the technological know-how, infrastructure and capital to overcome changes in climate. Moreover, most of the TFP growth in non-poor countries is attributed to the tertiary or service sector where the exposure to hotter temperatures is less compared to poor countries where agriculture and manufacturing constitute a major part of TFP growth. This ex-ante expectation of observing heterogeneity in the impact on TFP growth motivates examining the different impacts of climate change by different categories. This paper looks at the impacts of climate on poor/non-poor, hot/non-hot, and both hot and poor countries to precisely capture these expected heterogeneity effects.

Letta and Tol (2019) have argued that climate change has had a negative and significant impact on TFP only in case of poor countries. When the hot-country dummy is added to their model, the negative impact gets reduced. Oritz-Bobea et al. (2021), meanwhile, have found a stronger 21 percent reduction in agricultural TFP since 1961 due to climate effects. Both sets of authors have constructed their regression models with subsequent additions of categories (like affluence of countries, and mean temperatures of countries), and found results different from the previous global aggregate. Oritz-Bobea et al. (2021) have found a strong negative relation because agricultural TFP is intuitively expected to be impacted the highest by climate change. This paper uses Letta and Tol (2019) as a base, but uses a simpler regression model with a linear climate function. Instead of adding temperature and income dummies to the model, the same simple model is run for a subset of poor or hot countries. The paper hopes to enhance the existing literature by using a simpler model to capture the heterogeneity effects of climate change on TFP growth.

Data and Descriptive Statistics

This section talks about the dataset and provides some descriptive statistics to motivate the analysis. The paper uses two cross-country panel datasets, one for gaining TFP data and the other for gaining climate data. For the time series data on temperature and precipitation, the data is taken from Climatic Research Unit (University of East Anglia). The data on TFP is taken from Our World in Data, which cites the Penn World table (2019) as their primary data source.

Table 1 presents the summary statistics for the various subsets of the data. Column 'All' consists of all the 116 countries. Some stark differences in the mean values of hot versus non-hot countries are already visible. There was also a significant overlap between poor and hot countries: 62 percent of the poor countries in this sample were also hot countries.

Table 1: Summary statistics for various subsets of the data

	All	Poor	Non-poor	Hot	Non-hot
Mean Annual Temperature (°C)	17.300	19.111	15.488	24.200	10.397
Temperature Change	0.024	0.019	0.020	0.015	0.024
Mean Annual Precipitation (mm)	88.514	87.319	89.709	111.568	65.460
Precipitation Change	0.042	0.044	0.038	0.049	0.033
ln TFP	-0.029	0.008	-0.062	0.016	-0.076
Growth of ln TFP	0.216	0.051	0.359	-0.278	0.729

Next, we visually examine the relation between climate and TFP growth. Figures 1 and 2 seem to deceptively suggest that there is negligible impact of climate change on TFP growth. However, it is important to note that both the figures capture only the average effects. Within each scatter plot, there seems to be a heterogeneity of experiences that is getting averaged out. These scatter plots provide further motivation to examine the effects of climate change by subsets of hot/non-hot and poor/non-poor countries.

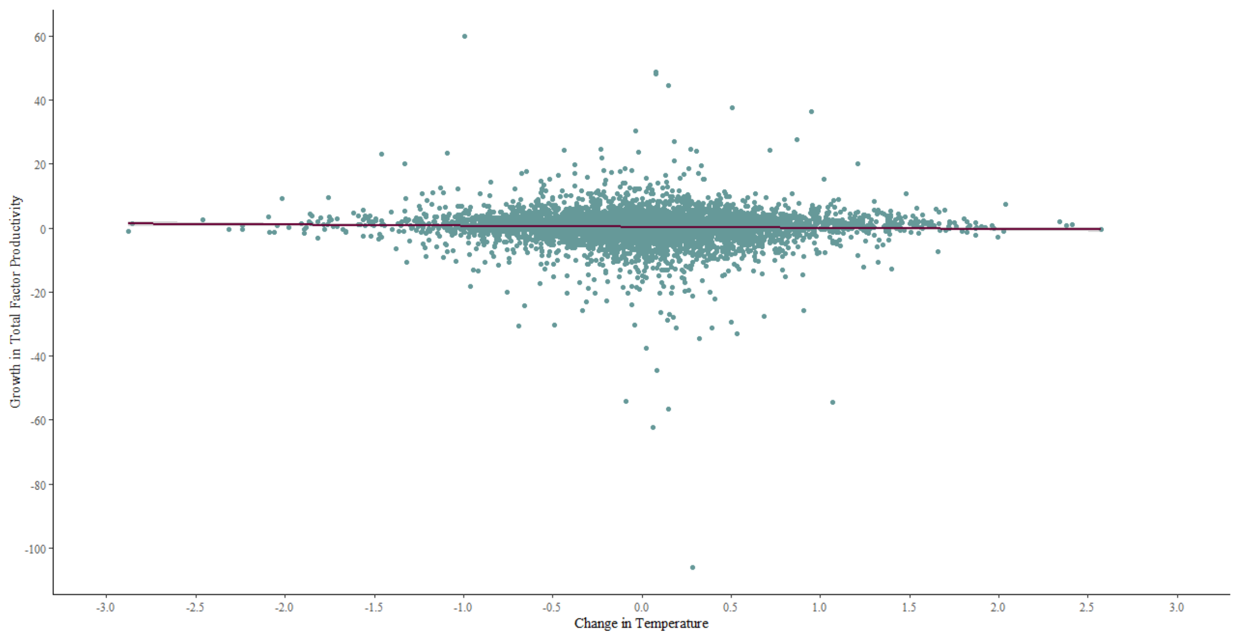

Figure 1: The above scatter suggests no impact of change in temperature on the growth of TFP.

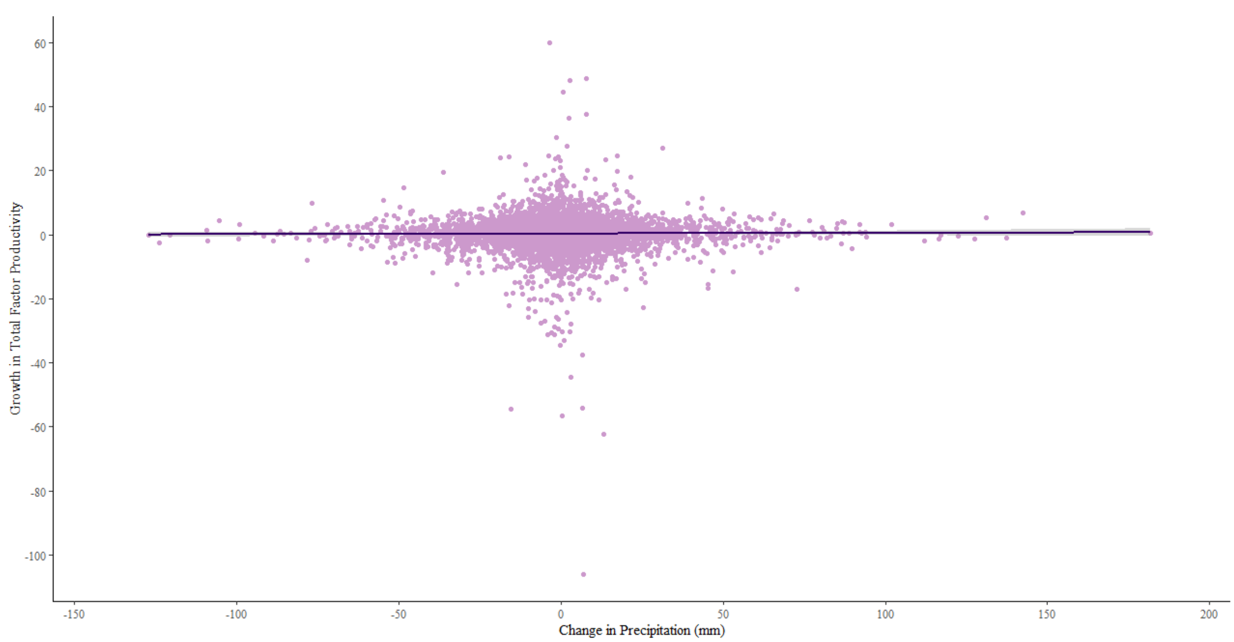

Figure 2: The above scatter suggests no impact of change in precipitation on the growth of TFP.

Empirical Strategy

To make the connection between climate and TFP, variables that represent temperature and precipitation normals were added to Solow's growth model. That establishes the possibility that climate variables can affect TFP. The following equations use some manipulations to finally equate TFP on one side, and a climate change variable on the other side.

$$lnY_{it} = lnA_{it} + \alpha lnL_{it} + (1-\alpha)lnK_{it} + lnu_{it} + \Delta f(T) + \Delta f(P)$$

Here, Y_{it} stands for the output of country i in time (year) t. A is Solow's residual or state of technology. L is labour and K is capital, while u is the error term in the regression or the unobserved variables. In $\Delta f(T)$, T stands for the temperature normal, while in $\Delta f(P)$, P stands for the precipitation normal. In the climate change literature, climate variables are typically modelled as quadratic functions that have a threshold value/ tipping point. This paper uses a simpler linear climate function. The above equation can be further manipulated:

$$lnY_{it} - \alpha lnL_{it} - (1-\alpha)lnK_{it} = lnA_{it} + lnu_{it} + \Delta f(T) + \Delta f(P)$$

Here, the left hand side is the same as the change in log of TFP.

$$\Delta ln\text{TFP}_{it} = lnA_{it} + lnu_{it} + \Delta f(T) + \Delta f(P)$$

The above equation, when fed into a panel data regression model will look like this:

$$\Delta ln\text{TFP}_{it} = \beta_1 \Delta T + \beta_2 \Delta P + \text{Year}_t + \text{Country}_i + lnu_{it}$$

The above model tries to overcome omitted variable bias (to a certain extent) by eliminating unobserved time-invariant variables. This is done by accounting for time and country fixed effects. As previously mentioned, the model was run on different subsets of data, first with all 116 countries, followed by only poor and only non-poor countries, followed by only hot and only non-hot countries, and lastly followed by countries that are both poor and hot. A country was classified as poor if its average GDP per-capita was lesser than the median average GDP per-capita of all countries. Similarly, a country was classified as hot if its mean annual temperature was lesser than the median of mean annual temperatures of all countries.

Empirical Results

Table 2 presents the regression results for all subsets of the data after correcting for hetroskedasticity by using robust standard errors. Firstly, the results indicate that the most significant cause for changes in TFP growth is temperature change and not rainfall change. None of the coefficients that estimate precipitation change have significant values. Moreover, countries that are both poor and hot experience the highest reduction in TFP growth as a result of changes in temperature. This implies serious consequences for the growth of developing countries, which typically have tropical climates and low per-capita GDP. Further, the differential impacts of temperature change on TFP growth in poor versus non-poor countries and hot versus non-hot countries are quite stark. A one degree change in temperature will reduce TFP growth by 0.908 percent in a poor country, while the same one degree change will have an insignificant impact on a non-poor country. Columns 4 and 5 of Table 2 again indicate that hotter countries are more affected by changes in temperature than colder countries. This clearly indicates that the null hypothesis of a change in temperature, that has no effect on TFP growth (as Figure 1 suggests) can be rejected in favor of the fact that a change in temperature has a significant effect on TFP growth.

Table 2: Effect of climate on TFP growth, various models.

	Dependent variable:					
	TFP Growth					
	All	Poor	Non-poor	Hot	Non-hot	Poor + Hot
	(1)	(2)	(3)	(4)	(5)	(6)
Temperature Change	-0.403^{***}	-0.908^{***}	-0.169	-1.015^{***}	-0.294^{**}	-1.363^{***}
	(0.121)	(0.305)	(0.109)	(0.296)	(0.142)	(0.460)
Precipitation Change	0.001	0.004	-0.003	0.002	-0.002	0.004
	(0.003)	(0.004)	(0.003)	(0.003)	(0.004)	(0.005)
Observations	5,580	2,591	2,989	2,838	2,742	1,732
R^2	0.050	0.048	0.119	0.052	0.098	0.052
Adjusted R^2	0.019	0.004	0.083	0.012	0.059	-0.002
F Statistic	4.811^{***} (df = 59; 5405)	2.125^{***} (df = 59; 2474)	6.552^{***} (df = 59; 2872)	2.543^{***} (df = 59; 2721)	4.853^{***} (df = 59; 2625)	1.524^{***} (df = 59; 1637)
Note:						*p<0.1; **p<0.05; ***p<0.01

Discussion and Conclusion

The first finding implies that the most significant cause for changes in TFP growth is temperature and not rainfall. It is important to think about why this might be the case. A possibile reason is that this paper considers all sectors (industrial, agricultural, and service sector) in the TFP calculation. It could be the case that rainfall predominantly affects agricultural TFP growth, but the effect gets averaged out with other sectors in the calculation. It is intuitive that barring agriculture, most of the exposure in other sectors is due to hotter days which affects productivity. One limitation of this paper is thus, that it cannot uncover the effects of temperature and rainfall on different sectors.

Another important finding is that a degree change in temperature reduces TFP growth by 0.908 percent in a poor country, while it has an insignificant impact on a non-poor country. A plausible explanation for this finding is the geography: 62 percent of the poor countries in this sample are also hot countries. Poor countries are also situated in more tropical regions and therefore more affected by changes in climate. Another reason could be adaptation. Non-poor countries have the technological know-how, infrastructure and capital to overcome changes in climate. Lastly, most of the TFP growth in non-poor countries is attributed to the tertiary or service sector where the exposure to hotter temperatures is less compared to poor countries (where agriculture and manufacturing constitute a major part of TFP growth). In other words, heterogeneity in exposure to hotter temperatures can possibly explain the declining TFP growth in poor countries as opposed to non-poor countries.

To conclude, this paper has enhanced the literature by showing that the impact of climate (specifically temperature) change on TFP growth is negative and significant. The countries that are both poor and hot are the worst impacted by a degree rise in temperature. The main driver of this reduction in TFP growth is coming from the fact that a country is hot - the geography matters more. This has serious implications for the growth of developing countries, which are predominantly located in tropical regions and have a low per-capita GDP.

References

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