Private Enterprise Development in Low-Income Countries

The Light and the Heat: Productivity Co-benefits of Energy-Saving Technology

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This study explores the consequences of the adoption of energy-efficient LED lighting in garment factories around Bangalore, India. We find that LED lighting, which emits less heat than conventional bulbs, decreases the temperature on factory floors, and thus raises productivity, particularly on hot days. These significant productivity gains imply high private returns to adopting LED lighting, in addition to its energy-efficient characteristics.

Background

Innovations in energy efficiency have been cited as a primary means to curb the acceleration of climate change[1]. Despite this promise, energy efficient technologies are consistently adopted at low rates[2]. Given the massive repercussions of global temperature increases due to climate change[3], and the startling rate of growth of global energy demand[4], achieving high adoption rates of these technologies is a key policy priority. Further, as economies in many low-income countries undergo major structural transformations away from agriculture and into manufacturing and services sectors, understanding effects of higher temperatures in sectors other than agriculture is increasingly important.

In this study, we estimate the impacts of higher temperature on productivity, as well as the productivity consequences of the adoption of energy-saving technology in garment factories in and around Bangalore, India. Global apparel is one of the largest export sectors in the world, and vitally important for economic growth in developing countries. India is the world's second largest producer of textile and garments, with the export value totalling $10.7 billion in 2009-2010[5].

We show that the introduction of light-emitting diode (LED) technology substantially attenuates the negative relationship between temperature and productivity. This is because LEDs dissipates less heat than conventional lighting used in factories, and during hotter days, this provides a more comfortable work environment, providing productivity benefits as well as energy savings.

Figure 1: Garment Factory Production Floor

Data Collection

We use line-level daily production data from 30 garment factories for about 3 years (April 2010 to June 2013) in and around Bangalore, India. Our measure of productivity is actual efficiency, which is equal to quantity produced divided by target quantity in a given day by a production line. We match this data to daily temperature, precipitation and relative humidity data, as well as timing of the introduction of LED lighting.

[1] Granade *et al* (2009). Unlocking energy efficiency in the US economy

[2] Knittel & Sandler (2011). Cleaning the bathwater with the baby: The health co-benefits of carbon pricing in transportation. NBER WP

[3] IPCC 5th Assessment Report "Climate Change 2013: The Physical Science Basis". Cambridge University Press

[4] Wolfram, *et al* (2012). How will energy demand develop in the developing world? JEP, 26(1):119–38

[5] Staritz (2010). Making the Cut? Low-income Countries and the Global Clothing Value Chain in a Post-quota and Post-crisis World

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Temperature-Productivity Gradient

First, we seek to establish the relationship between temperature and line-level productivity, the productivity-temperature gradient. We allow for the fact that temperature may impact productivity differently at higher or lower levels of temperature, by focusing on the different effect of temperature below or above 19 degrees Celsius wet bulb globe temperature (WBGT)[6]. We control for budgeted efficiency, precipitation, as well as line-level, factory by year, factory by month and day of the week fixed effects.[7]

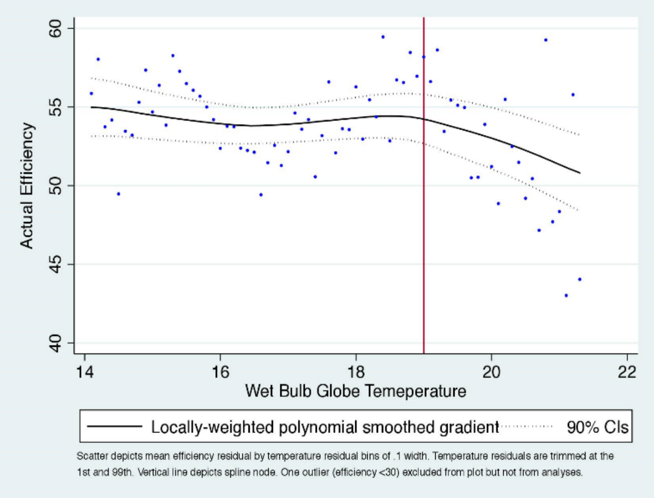

Figure 2: Efficiency versus Temperature (before introduction of LED lighting)

The regression results indicate that productivity is roughly unaffected by changes in temperatures when the temperature is still low, but at higher levels of temperature, further increases have a large negative impact on productivity. Specifically, above 19 degrees, a one degree increase in temperature leads to a reduction of more than 2.1 percentage points in actual efficiency, which is about 4% of the average efficiency. Figure 2 illustrates the raw productivity-temperature relationship, with a relatively flat gradient before 19 degrees WBGT, and a steeply negative gradient after. An analysis of daily average line-level attendance reveals that attendance is not impacted by temperature, leading us to conclude that the productivity impacts are likely driven by heat stress rather than lower attendance or a change in the composition of workers who attend on hotter days.

Effect of LED on the Temperature-Efficiency Gradient

We now estimate the effect of LED lighting on the relationship between outside temperature and productivity by conducting similar analyses as above. We find that LED lighting has no significant impact on the slope of the efficiency-temperature gradient below 19 degrees Celsius WBGT, but a strong attenuating impact on the negative slope of the gradient above 19 degrees. Our estimates indicate that the introduction of LED offsets the negative impacts of temperature on efficiency by roughly 85%, attenuating the magnitude of the negative slope above 19 degrees from around -2 to roughly -0.3. Figure 3 illustrates the raw productivity-temperature relationship with (blue line) and without (red line) LED lighting, with a clear flattening of the curve after LED introduction above 19 degrees.

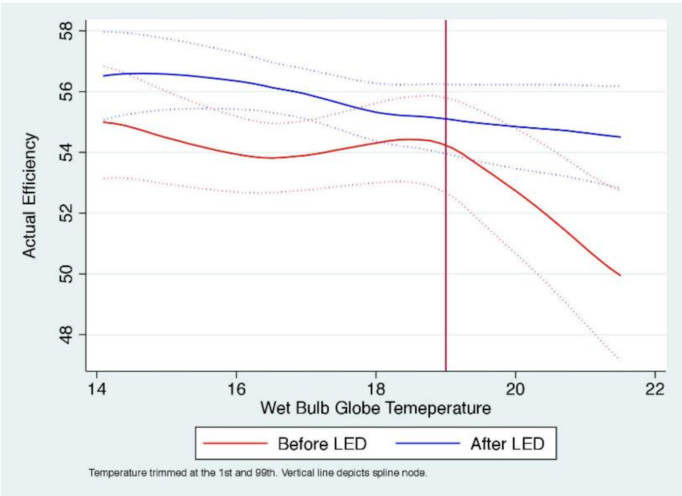

Figure 3: Efficiency versus Temperature, before and after LED

[6] Wet Bulb Globe Temperature (WBGT) is a measure of temperature that accounts for relative humidity. The 19 WBGT degrees cut-off corresponds in our data to indoor dry bulb temperature of roughly 29.5 degrees before LED introduction.

[7] For more details on the estimation strategy and various specifications, please see to the authors' working paper here.

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Co-Benefits of Energy-Efficient Technology and Cost-Benefit Analysis of Adoption

We calculate the average total productivity impact of LED installation by using our estimator of the specific effect at each observed temperature and the taking into account the underlying probability distribution of temperature. We find an average total increase in production efficiency of roughly .7 percentage points (or more than 1% improved productivity from the mean). The cost-benefit analysis of LED adoption at factory level is as follows:

- ***Profit gains from productivity increases:*** Senior firm management with whom we worked closely on this study estimated that each percentage point gain in efficiency was translated into a 0.2 percentage points profit gain. Thus, a 0.7 percentage point gain in efficiency from LED installation translates to a .14 percentage point gain in profits. At an approximate profit value per factory per year of 400,000 USD, the introduction of LED results in increased profits of 14,088 USD per factory per year from gains in production efficiency.

- ***Energy savings from using LED rather CFL bulbs*:** Management estimated that the total energy cost savings per year per factory unit of LEDs (as compared with CFL bulbs, which were being used before LED introduction) were approximately 2.40 USD per bulb replaced or roughly 2,863 USD in total for an average replacement of 1193 bulbs per factory in our data.

- ***Cost of replacement:*** The cost of replacing the average factory's bulbs to LEDs is ~10,180 USD.

Thus, if only energy savings were taken into account, it would take more than 3 and half years to break even. However, when the productivity benefits are included, the firm breaks even in just over 7 months after LED installation. After this initial payback period, the firm benefits from an on-going combined increase in profitability from energy savings and efficiency gains of roughly 4.2 % or an increase in their profit margin of .17 percentage points.

Moving Forward…

The promise of climate change mitigation hinges on the willingness of individuals and firms to adopt energy-saving technologies on a large scale. This willingness, in turn, is a function of the private returns to adoption, which, for most mitigation strategies, are cited as low or negative even when the public benefits are large.

In this study, we showed that in the case of LED lighting, not only is there no trade-off between the adoption of an energy-saving technology and firm profits, but also that there are strong private gains that arise through the productivity co-benefits of LED lighting, which attenuates the negative effect of high temperatures on efficiency by dissipating less heat. More details on this project can be found in our working paper.

While our work is an important first step in quantifying private co-benefits of climate change mitigation strategies, much more needs to be done to quantify the full returns to the variety of mitigation strategies. For example, as Knittel and Sandler (2011) suggest, carbon taxes likely have health benefits due to decreases in local air pollution. If consumers internalize these benefits, the effective costs of the tax will be substantially lower. Whether similar co-benefits exist for other types of mitigation – e.g., renewable energy investments, public transport systems, energy-efficient built environments, etc. – is an open and vital question.

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