Agricultural Productivity, Factor Reallocation, and Industrial Production in the Short Run: Evidence from India[1]

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Extended Abstract

This paper explores whether short-run changes in agricultural productivity result in factor reallocation into the formal manufacturing sector, and whether adjustment costs impede this process of reallocation. Drawing on the results from a simple theoretical framework, I combine household-, firm-, and district-level data with high-resolution atmospheric data to examine the effects of weather, a strong driver of short-run agricultural productivity, on industrial production and labour market outcomes in India. While temperature increases are shown to have a significant negative effect on agricultural yields ($26.5\%/1°C$) and wages ($7.1\%/1°C$), the estimated effect on manufacturing outcomes is zero. By exploiting spatial variation in, and firm-level exposure to, India's labour regulation environment I demonstrate that the estimated effect is not a true zero, but a net zero. Comparing the effect in rigid labour markets to the effect in flexible labour markets provides an estimate of the economic consequences of factor reallocation, net of the remaining channels. In rigid labour markets with fewer employment opportunities, the production and employment of registered firms contracts. However, in flexible labour markets, where workers can more easily adjust between the factory and the field, registered firms expand production ($9.3\%/1°C$) and employment ($10.2\%/1°C$), due to a fall in the equilibrium wage ($4.5\%/1°C$), offsetting the contraction effect. These results are shown to be consistent at the macroeconomic level through the use of district × sector GDP.

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channels. In rigid labour markets with fewer employment opportunities, the production and employment of registered firms contracts. However, in flexible labour markets, where workers can more easily adjust between the factory and the field, registered firms expand production ($9.3\%/1°C$) and employment ($10.2\%/1°C$), due to a fall in the equilibrium wage ($4.5\%/1°C$), offsetting the contraction effect. These results are shown to be consistent at the macroeconomic level through the use of district $\times$ sector GDP.

To begin, I construct a simple theoretical framework that illustrates the general equilibrium effects of sector-specific productivity shocks in the presence of factor market distortions (section 3). The model indicates that a change in agricultural productivity, resulting in a change in relative productivities between the two sectors, should result in a movement of labour from agriculture into manufacturing, conditional on there being external demand for manufactured goods. However, with the presence of adjustment costs in the manufacturing sector, reallocation is impeded resulting in misallocation.

Drawing on the results from this framework, I combine data at the household-, firm-, and district-level with data containing high-resolution atmospheric parameters to examine the effects of weather, an important driver of short-run agricultural productivity, on industrial production and labour market outcomes in India between 2001 and 2007. In order to understand the degree to which weather is a driver of factor reallocation between agriculture and manufacturing, there are several empirical stages, drawn from the theory, that need to be demonstrated. First, does weather affect agricultural production? Secondly, does weather affect agricultural wages? Finally, does weather affect production and labour market outcomes in manufacturing markets through factor reallocation?

I begin by testing the hypothesis that weather is an important driver of short-run agricultural productivity. Consistent with many other papers that have explored this relationship in India I show that an increase in temperature has a significant negative effect on agricultural yields (26.5%/1°C). However, across multiple weather datasets rainfall is shown to have little explanatory power once temperature is controlled for. Secondly, I test the hypothesis that a reduction in agricultural productivity transmits into reduced agricultural wages, a necessary condition for factor reallocation to arise (section 5.2). I compute the average day wage for agricultural labour in each district from household data to test this hypothesis. Consistent with the results on agricultural yields, I observe that an increase in temperature is associated with a reduction in agricultural wages (7.1%/1°C), while changes in rainfall are shown to have no effect, consistent with the observed effect on yields.

The final stage of analysis is more complicated and faces a number of empirical challenges. The use of weather data in empirical analysis is a blessing and a curse. On the one hand, the realisation of weather is exogenous and so provides variation in short-run agricultural productivity. On the other hand, for empirical estimates of weather on manufacturing outcomes to be interpreted as the result of factor reallocation between agriculture and manufacturing we require the assumption that these outcomes are not affected by weather in any other way, either directly or through additional agricultural channels. This is an very strong assumption as there are many potential channels through which weather could have affect manufacturing, both through agriculture and directly. Changes in agricultural productivity could also affect manufacturing outcomes in sectors that use agricultural products as inputs. In addition, a reduction in agricultural income could reduce the consumption base for manufactured products with local demand, more likely in the informal manufacturing sector (Rijkers and Soderbom, 2013). Weather may also affect manufacturing production directly through its impact on factors of production. For example, An increase in temperature may reduce production through a reduction in the health, physical, or cognitive ability of workers and managers, or through an increase in absenteeism due to avoidance behaviour (Mackworth, 1946; 1947; Kenrick and MacFarlane, 1986; Hsiang, 2010; Cachon et al., 2012; Dunne et al., 2013; Advharyu et al. 2014; Burgess et al., 2014; Sudarshan and Tewari, 2014; Heal and Park, 2014; Graff Zivin and Neidell, 2014; Graff Zivin et al. 2014). Heavy rainfall may affect workers' ability to get to work (Bandiera et al., 2013), or disrupt supply chains. Increased temperature, or a reduction in rainfall in areas dependent on hydroelectric power generation, is likely to put additional stress on an already fragile electricity infrastructure reducing the supply of electrical power (Alcott et al., 2014; Ryan, 2014). Finally, capital stocks and flows may be affected if weather affects capital depreciation, the relative productivity of inputs, or the level of investment in the economy if capital is locally constrained (Asher and Novosad, 2014).[2] The difficulty associated with interpreting empirical estimates of weather variation are particularly stark in the context of this paper. Estimates of the net effect of temperature and rainfall on manufacturing outcomes are shown to be zero (section 5.3). The question remains as to whether these estimates are true zero's or the net effect of competing channels.[3]

Given this ambiguity it is very difficult to interpret the empirical estimates of weather elasticities in a meaningful way. Where empirically relevant channels move in the same direction we fail to have an economic interpretation that can be used to aid the design of appropriate interventions to mitigate losses or exploit opportunities. Where multiple channels are competing economic losses and opportunities may be missed entirely or substantially underestimated. To understand the empirical relevance of a single channel an identification

[2] Under the assumption that labour is more sensitive to temperature increases than capital, firms may shift towards more capital intensive production resulting in capital deepening.

[3] Due to the potential for multiple channels I refrain from the use of these weather variables as instrumental variables due to the clear violation of the exclusion restriction.

strategy is needed that *"switches off"* the channel of interest for a subsample of the data, such that the difference between the empirical estimate for these two samples backs out the direction and magnitude of the effect, net of the remaining empirically relevant channels.

By exploiting spatial variation in, and firm-level exposure to, India's labour regulation environment I identify the effects of short-run factor reallocation on manufacturing production and labour market outcomes through its interaction with year-to-year changes in weather variation (section 5.4). By comparing the net effect of temperature on regulated firms in rigid labour market environments to regulated firms in flexible labour market environments, the factor reallocation effect is backed out as the only mechanism that varies across the two groups – all remaining channels cancel out in the estimation. I estimate that an increase in temperature is associated with a factor reallocation effect that increases production (9.3%/1°C) and employment (10.2%/1°C), alongside a reduction in the average day wage (4.5%/1°C).[4] These results are consistent with the theoretical prediction that a reduction in the equilibrium wage reduces the cost of production increasing external demand for manufactured products. Additional robustness tests and evidence provide additional support for this claim.

A main consideration is the type of worker that shifts between the factory and the field. It is reasonable to think that there are fundamental differences between the migrant workers that respond to a reduction in agricultural productivity and the workers that form the permanent labour force in the manufacturing sector. The data allows us to distinguish between contract and permanent workers within the firm, providing the opportunity to better understand the relationship between these workers, as well as test the credibility of the papers narrative. Consequently, estimating the factor reallocation effect on permanent workers, provides an estimate of the effects of an influx of these "migrant" workers on the employment outcomes of the "native" labour force. This requires the assumption that permanent manufacturing workers do not move between agriculture and manufacturing, i.e., we must believe that firms are hiring migrant workers as temporary contract workers, rather than permanent workers.

Given the differences between contract and permanent workers it is also important for the identification strategy to consider the degree to which the labour regulation environment has a binding effect on contract workers, if at all. I find suggestive evidence that the use of contract workers alongside permanent workers results in production complementarities. This is encouraging from an identification perspective as the labour regulation environment will

[4] All results within manufacturing are conditional on the firm surviving year-to-year changes in weather variation, however, firm exit seems unlikely to be a major consideration in this context (formal tests are forthcoming).

therefore likely have a binding effect on contract workers even if they are not covered directly through their employment in the factory. The premise that contract workers and permanent workers could be complements is plausible as section 10 of the 1970 Contract Labour Act prohibits the use contract labour if the work *"... is done ordinarily through regular workmen in that establishment."* Consequently, it may be reasonable to think that by hiring contract workers, permanent workers are able to engage in their activities more productively.

In order to understand the timing of adjustment I exploit within-year variation in the agricultural season. The results show that the production and wage effects for both types, as well as the employment effects for permanent workers are realised during the growing season, when agricultural productivity is realised. However, rural-urban migration arises during the lean season when there are more opportunities, travel is more feasible before the onset of the monsoon rains, and temperatures may affect migration through anticipation about future employment opportunities in agriculture. Migrants are known to work during the lean season and return to rural areas upon the realisation of agricultural productivity. If migrants waited until the agricultural outcome was realised there would be fewer opportunities to work. Furthermore, agricultural work is more flexible on a daily basis, while factory jobs, even for contract workers, are longer-term. Consistent with this we observe that an increase in temperature during the lean season is associated with an increase in the number of employed contract workers. This may be due to anticipation effects or avoidance behaviour. What emerges is that if a good agricultural outcome is realised and migrants return to work in the fields, there is little economic effect on manufacturing production. By contrast, a bad agricultural outcome reduces demand for labour and so migrant workers remain in the factory, resulting in significant economic effects, directly, and through an increase in the productivity of the permanent labour force.

To provide supporting evidence for the premise that factor reallocation is driven by an increase in external demand for manufactured products I examine the effects of weather on an additional dataset comprising district-level shares of total manufacturing and agricultural exports. I observe that, in districts with rigid labour market environments, an increase in temperature is associated with a reduction in manufacturing exports, relative to districts with flexible labour markets, supporting the narrative of a positive factor reallocation effect. The magnitude of these effects are similar to the empirical estimates at the firm-level.[5] For sectors dependent on local demand we would expect to see a decline in output due to a reduction in the total income, and consequently the consumption base, of the local economy (Soderbom

[5]We assume either that the agricultural sector is tradable, or that subsistence constraints are non-binding. The first assumption appears to be a better representation of India due to the Public Distribution System, and the integration of Indian agriculture in global markets. In the case of a small open economy subsistence constraints are non-binding as long as production in the global economy is enough to meet the constraint.

and Rijkers, 2013). However, economic losses to sectors dependent on local demand are likely to be mitigated in areas with a greater share of production in tradable manufacturing. While the competitive wage falls the number of hours worked in areas with external demand increases compared to areas that serve only local demand, where both the wage and the demand for labour falls. Consequently, in diversified economies with production in tradable goods the reduction in demand for labour is offset, mitigating in part reductions in demand for non-tradable sectors. This emphasises the importance of economic diversification and integration in mitigating local productivity shocks (Autor et al., 2013; Costinot et al. 2012; Foster and Rosenzweig, 2004; Hornbeck and Keskin, 2012; Jayachandran, 2006; Mian and Sufi, 2012; Moretti, 2011).

Finally, I demonstrate that the results observed at the firm-level are consistently estimated at the aggregate level. Using district-level GDP I estimate a factor reallocation effect of consistent in sign and magnitude to estimates at the firm level for the manufacturing sector. By contrast, the effect is insignificant for other unregulated sectors. This provides further support for the identification strategy, namely that the estimated results are driven by the labour regulation environment, rather than other confounding factors.

Collectively, these results provide robust support for the premise that a short-run decline in agricultural productivity results in employment adjustment from farm to factory. In addition the results highlight the economic losses associated with adjustment costs, provide suggestive evidence about the relationship between contract and permanent workers in the manufacturing sector, and call attention to the empirical challenges associated with the use of atmospheric data in econometric analysis. Most importantly the results indicate the importance of analysing productivity shocks in a general equilibrium framework, reducing the risk of introducing substantial bias to empirical estimates by under- or over-estimate economic losses and/or opportunities.