Essay

An Examination of the Long-Run Adjustments caused by Environmental Degradation on Land Use, Land Value and Agricultural Productivity

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Outline

Central Paper:

Hornbeck, R., & Keskin, P. (2014). The Historically Evolving Impact of the Ogallala Aquifer: Agricultural Adaptation to Groundwater and Drought. *American Economic Journal: Applied Economics*, *6*(1), 190–219. http://www.jstor.org/stable/43189470.

Research question: What are the long-run economic consequences of environmental shocks and consequent degradation in terms of agricultural productivity, land value and land use?

Hypothesis: Short-run consequences involving environmental degradation can be quite severe. However, while there are mechanisms e.g. price adjustments, labor migration and industrial transformation, which allow for recovery in the long-run, environmental assets and capital do not recover to their original value, meaning that some damage may be irreversible.

Significance: This question is pertinent to the challenges faced today with respect to the deleterious effects of climate change and other types of environmental degradation, in particular, in vulnerable local regions and countries like least developed countries, small islands, tropical areas and deserts, population-dense areas, and water-scarce areas.

Methodology:

1. Identify and review papers that examine the effects of environmental degradation as it pertains to agricultural productivity and land value.

2. Construct literature review to describe the background, data sources, empirical strategy and major findings.

3. Briefly explain whether the findings are consistent with the hypothesis, the extent of agreement and significance of findings, and the appropriateness of the methodologies.

Introduction

The underlying premise being examined is the assumption that short-run environmental impacts are ultimately re-balanced by long-run economic adjustments. However, free market mechanisms and policy implements do not always ensure that environmental assets regain their original value.

This essay surveys a number of scholarly articles which focus on the impacts of environmental degradation and what types of adjustments prevail. The essay also looks at the long-run impacts of these adjustments, what factors affect environmental degradation and how outcomes are measured.

The major findings of this essay are that long-run adjustments do not necessarily result in recovery of the environmental asset to its original value. This is due to a combination of policy choices, market failures and other types of adjustments.

Researchers typically use linear regression and a differences in differences (D in D) empirical strategy to account for time and fixed effects, as well as, interaction and quadratic terms.

Literature review

Central paper

The 1930s American Dust Bowl was an environmental disaster in parts of Kansas, Colorado and Oklahoma where large dust storms permanently removed as much as 75% of the topsoil (Hornbeck, 2012). The author discusses the environmentally deleterious impacts of the 1930s American Dust Bowl on land values, revenues and emigration. He articulates the long-run economic adjustments, in particular, the delayed effects of adjusting agricultural techniques and altering land use patterns, as well as, the substantial out-migration to less affected regions. The paper compares changes between more- and less-eroded areas.

The central paper establishes the framework and assumptions under which other scholar works are scrutinized within this paper. There is some debate in the literature about how best to measure outcomes. Hornbeck (2012) examines the outcome of land value assuming its dependence on agricultural output and focuses on the speed and scope of adjustment; however, other papers use agricultural profit and relative environmental changes.

Hornbeck (2012) explains that the environmental shock of the Dust Bowl reduces land rents in both the short- and long-term, causing land value to immediately decrease. The author outlines a theoretical model which defines how, after an economic shock, adjustments are costly in the short-run and land allocation is binding, leading to a decrease in lands rents and land value. In the long-run, however, adjustments occur through shifts to other factors of production or technology, and land rents and values recover. This model is used to justify the use of land values in the empirical examination.

The author describes two key mechanisms, using a general equilibrium model and assuming inelastic supply of land and clearing markets, which can distort the measurement of effects:

1. As production decreases in eroded areas and shifts to non-eroded areas, crop prices and thus demand for non-eroded land increases, thereby overstating the subsequent decline in land values of the eroded areas.
2. As workers move to non-eroded areas or to the industrial sector, wages are lower in eroded areas in the agricultural sector thereby encouraging labour intensive agricultural production. Simultaneously, as labour shifts to other sectors and areas wages decline stimulating industrial production. The effect is an understating of wage declines and overstating of out-migration.

Hornbeck (2012) uses data from the US census of agriculture, census of population and census of manufacturing, the Federal Deposit Insurance Corporation, Office of Government Reports and the National Climatic Data Center. The data describes agricultural and animal husbandry land use, revenue and capital, acreage, farm and rural population, retail sales and unemployment, droughts, among other factors. Differential erosion is proxied by cumulative erosion damage to account for omitted variable bias (OVB) due to lack erosion prior to the 1930s. Pre-1930s variables for county characteristics are also used to account for OVB to the extent that prior land usage may predict erosion in the Dust Bowl era and that these are correlated with the outcome variable.

The empirical strategy estimates "…average changes for more-eroded counties, relative to changes for less eroded counties in the same state and with similar pre-1930s characteristics…" (Hornbeck, 2012, pg. 1486). The outcome variable, Y_{ct}, represents this value indexed for county, c, and year, t, is differenced from its value in 1930, and is regressed on "…the fraction of the county in medium erosion (M_c) and high-erosion (H_c) regions, a state-by-year fixed effect (α_{st}), pre-1930s county characteristics (X_c), and an error term (ε_{ct})…" (Hornbeck, 2012, pg. 1486) as follows:

$$Y_{ct} - Y_{c1930} = \beta_{1t}M_c + \beta_{2t}H_c + \alpha_{st} + \theta_t X_c + \varepsilon_{ct}$$

A D in D approach with the treatment being the level of erosion (high or medium) is applied using linear regressions for each county and year, including the control variables for fixed effects and outcome variables comparing changes pre-1930s to post-1930s. The identification assumption maintains that the measured rate of change in erosion would be the same for different pre-conditions in separate regions. Causality is established by singling out the impact of the Dust Bowl on different regions. The coefficients of interest, β_{1t} ***and*** β_{2t}, represent different outcome parameters including, among many others, logs of land value, acreage used and population proportions. Slope coefficients are pooled and averaged to give scalar representations over time.

The paper finds that agricultural land values declined more with higher levels of erosion and that the changes were "substantial and persistent" (Hornbeck, 2012 pg. 1488). Slope coefficients were significant to 1%. For example, from 1930 to 1940 land values fell by 30% and 17% respectively for high- and medium-erosion counties. Longer-term estimates for 1945 show that the land value declines persisted more for higher erosion areas. There is no evidence of systematic recovery implying that long-run adjustments did not result in recovery of original land values. Agricultural revenue showed similar effects in both the short and long term. For more eroded counties, ultimate recovery was less than 25% of the initial difference in agricultural costs.

With respect to agricultural productivity in more eroded counties relative to less eroded, due to the inelastic supply of land, the proportion of land used in agriculture showed no significant decline through to the 1940s and moderate declines by the 1950s. Instead, adjustments were made in terms of land value. Because wheat production is more sensitive to soil quality, and due to policy recommendations to switch to hay, wheat productivity also declined in more eroded counties.

Interestingly, the study notes that there is evidence that some adjustments were delayed for 15 to 20 years. The author suggests that this is due to restricted access to capital, surplus labour due to suppressed wages, and land tenancy considerations where smaller farms could not afford the adjustment costs. Policy recommendations included reseeding and conversion to pasture but were likely hindered by small farm size. Additionally, national policy attempted to reduce production of certain crops to drive prices up to stimulate income growth. The effects of the Great Depression may have hindered economic recovery through the absence of jobs, out-migration with labor market equilibrium adjusting through population declines rather than capital inflows and local industry growth.

To examine these effects the previous specification is modified to include interaction terms between the log of the number of banks in 1928 and the fraction of a county in high- and medium-erosion regions. The estimated effect of access to capital is made possible by the identification assumption that the capital provided by more banks allowed those counties to be make adjustments faster which the author cautions is a strong assumption.

In the aftermath, much farmland was left significantly eroded with an estimated 25 to 40 year recovery period with primary adjustments through out-migration. The population in eroded areas steadily increased over the period but stagnated from 1930 to 1940 (below trend 1930 to 1960).

Other scholarly works

Hansen and Libecap (2003) provide a precursory study to Hornbeck (2012) on the origins of the Dust Bowl and, similarly attempt to explain why long-term adjustments were constrained and, in particular, enhance the explanation that over-cultivation and severe drought were the only causes. They analyze the impact of farm size on the extent of erosion by investigating the effects of cross-farm interactions and intensification due to prevalence of small farms (a consequence of the Homestead Act). As mentioned in Hornbeck (2012), Hansen and Libecap (2003, pg. 4) argue that "…optimal farm size for productive efficiency was smaller than for wind erosion control…"

The premise of the empirical study is that a minimum percentage of farmland must be fallowed for effective erosion protection and that farmers sought to maximize profits by balancing productive and fallowed acreage. The authors develop a model to assess the difference between regions where sufficiently large farms optimized erosion protections versus smaller farms that had to sacrifice fallow shares for productivity resulting in ineffective erosion controls.

Panel data was extracted from county-level agricultural census data from 1930 to 1964. The outcome variable, f_i, is the share of strip fallow acreage and is regressed on s_i and s_i^2 average farm size and its square and, d_i, the estimated standard deviation in farm size, where $\boldsymbol{i}$ indexes county:

$$\boldsymbol{f_i = a + b_1 si + b_2 si^2 + b_3 d_i + e_i}$$

The estimated slope for farm size is positive and significant, implying that the share of fallow acres increases with farm size. The relationship between the standard deviation of farm size and farm size is negative and significant, implying that that in regions of widely varying farm sizes, effective fallowing was reduced possibly reflecting deficiencies in coordination. This effect dissipated over time through to 1940 as average farm size increased. The authors conclude that the Dust Bowl is an example of a classic common-pool problem. The prevalence of small farms inhibited the coordination and effectiveness of erosion control and was not resolved until farms grew in size, thereby delaying the mitigation of the environmental shock. This is consistent with Hornbeck's (2012) findings.

Mendelsohn et al. (1994) analyze the effects of climate in terms of temperature and precipitation on average farm values in 3000 counties in the United States (U. S.). The authors describe a theoretical model within a "Ricardian" framework which involves examining the response to land value or net rent, and not specific crop yields. They explain that, in contrast to the traditional production function approach, the "Ricardian" approach allows for adjustment through substitution between alternatives for land use, such as switching crops. It is argued that traditional models overestimate the impacts of climate change by examining only one or a few inputs for say, corn, and not allowing substitution to say, grazing.

Data used includes county average land and building values, farm land usage, socioeconomic factors and soil characteristics gathered from 1982 *U. S. Census of Agriculture*, the *County and City Data Book*, and National Resource Inventory (NRI). Due to different zoning systems, spatial statistical analysis was performed to reconcile agricultural outcomes with climatic conditions.

Land values are regressed on climate, soil and socioeconomic factors to determine the best-value function. Linear and quadratic terms for climate are used where the linear term is interpreted as marginal values while the quadratic is interpreted as the response of the marginal effect as it moves away from the mean. A base model regression included only non-farm variables and was modified to include urban, soil and environmental factors as controls.

Generally, while the magnitude of effect may varies, all specifications suggest that higher winter and summer temperatures negatively impact crop yields, the opposite being true for autumn.

They also show that higher winter or spring precipitation is advantageous but the opposite is true for summer or autumn. For example, an increase of 1°F causes a land value decline of between $89 to $103. When global climate change is considered, the authors use an expected increase of 5°F and estimates losses of land value ranging from $119-$140 billion (1982 prices). In contrast, when revenues are used, they estimate an increase of $20-30 billion in farmland value. The authors advise caution in interpreting the results as effects are localized and contrasting especially when alternative land use is applied.

A paper by Burke and Emerick (2016) discuss agents' responses to patterns in temperature and precipitation and the resultant long-run agricultural outcomes. The authors highlight an important and recurring theme: decisive and extensive adjustment is critical to minimizing the negative economic impacts of climate change (and other environmental decline). The exogenous factors, temperature and precipitation, are the same as in Mendelson et al. (1994).

The authors describe a model where a farmer has choice between two crops - one which performs better in cooler climates and the other in warmer climates. The dependent variable is a dummy variable for output, y_{it}, and is regressed on the binary choice between the crops, x_{it}, the realized temperature, z_{it}, and a quadratic overall production technology with respect to temperature (***i*** and ***t*** index for farmer and period respectively):

$$y_{it} = \beta_0 + \beta_1 z_{it} + \beta_2 z_{it}^2 + x_{it}(\alpha_0 + \alpha_1 z_{it} + \alpha_2 z^2_{it})$$

The farmer responds to awareness of weather by the choice in which crop to produce and this reflects adaptation. The assumption here is that farmers' responses to weather are indicative of longer term responses to climate change. Data on crop area and yield are taken from the U. S. Department of Agriculture's National Agricultural Statistical Service.

The empirical regression involves changes in an agricultural outcome variable, Δy_{is}, and is regressed on changes in growing degree days (GDD) and changes in precipitation (***i*** and *s* index for county and state respectively):

$$\Delta y_{is} = \beta_1 \Delta GDD_{is;l0:l1} + \beta_2 \Delta GDD_{is;l1\infty} + \beta_3 \Delta Prec_{is;p<p0} + \beta_4 \Delta Prec_{is;p>p0} + \alpha_s + \Delta \varepsilon_{is}$$

GDD conceptually represents a measure of the amount of time a crop is exposed to a defined temperature range. The regression is described as a "piecewise linear function" (Burke and Emerick, 2016, pg. 116) which includes fixed effects for state and county and uses D in D approach to estimate the relationship between weather and outcomes where the treatment is GDD and precipitation.

The study finds that a single day instance of 30°C from the optimal 29°C results in a 0.5% decline in yields for corn. The authors determine that long-run measures mitigated about less than half of the short-run effects of extreme heat on corn yields and that there is limited adaptation among corn and soy farmers. They postulate that recent climate change adaptations have been minimal because of farmers exiting agriculture (selection), changes to operational and business processes, and governmental support programs. They project, using climate change modelling, that annual corn productivity will decrease by 15% by 2050.

The papers reviewed thus far have presented mostly negative impacts associated with environmental shocks and climate change. Deschênes and Greenstone (2007) propose a contrasting perspective. Their variable of interest, profits, is different to previous papers but is still a comparable measure of value. Their approach is similar to that of Mendelsohn et al. (1994) in that they attempt to account for farmers' alternative choices in adaptation other than altering the factor of production mix and is similar to Burke and Emerick (2016) in that they use GDD as a determinant. All three papers use random year to year variation in temperature and precipitation.

Data was sourced from various years' Census of Agriculture (agricultural), NRI (soil quality), Parameter Regressions on Independent Slopes Model (PRISM) (climate and weather), Intergovernmental Panel on Climate Change (IPCC) and Hadley Centre's Second Coupled Ocean-Atmosphere General Circulation Model (climate change predictions).

The dependent variable, y_{ct}, county-level agricultural profits, is regressed on county fixed effects, α_c, state by year fixed effects, γ_{st}, a vector of observable determinants of farmland values, $X'_{ct}\beta$, and annual realizations of weather, W_{ict} (c, t, and s index for county, state and year):

$$\boldsymbol{Y_{ct} = \alpha_c + \gamma_t + X'_{cr}\beta + \Sigma_i\, \theta_i f_i(W_{ict}) + u_{ct}}$$

This is a modification of a hedonic regression model (which they also run). Agricultural profits are used because of the assumption that while land values internalize long-run site characteristics and should not be responsive to weather, revenues and expenditures, and thus profits, are affected by weather. The coefficient on interest is θ which represents the response to weather that is uncorrelated to unobserved determinants of agricultural profit. This is D in D approach where the treatment is GDD and precipitation, and there are controls for fixed effects for county, state and year.

Their findings estimate that GDD is expected to rise on average per county by 1200 units and precipitation by 3 inches during the growing season. The preferred estimates show that climate change will result in $1.3 billion (2002$) or 4% rise in annual profits. Like Mendelsohn et al. (1994), effects were found to be heterogeneous across states. Predicted temperature and precipitation changes were found to have no substantial impact on corn or soybean crop yields in contrast to Burke and Emerick (2016). They conclude by comparing this new approach to the hedonic method, indicating that estimates using the latter produce higher ranges between -$200 billion to $320 billion ($2002) or -18% to 29% compared to previous papers' estimates.

Fisher et al. (2012) present a commentary on Deschênes and Greenstone (2007). They argue that there are irregularities in the environmental data and codes which reverse the direction of effects. They indicate that most of the variation is absorbed in the state-by-year fixed effects. In addition, other inconsistencies in the measurement of profits lead to OVB and invalidate the identification assumption that variations in weather causes changes in profits. They also highlight potential discontinuities within the data. By adjusting the data and replicating the empirical analysis, they produce contrasting results but acknowledge that consensus has not yet been established on the economic impact of global climate change.

Deschênes and Greenstone (2012) provide a reply and accept that there are irregularities and discontinuities in the data set, as well as, coding errors. Their reassessment of the study unveils three findings:

1. Agricultural profits are reduced.
2. Losses may be over-estimated because technological progress is not included.
3. Estimated losses are still smaller when compared to the results from the traditional approach.

They acknowledge that while the primary findings from their original paper appear to be inaccurate, there is still is no conclusive consensus that climate change will lead to negative agricultural consequences. Differences in conclusions between using outcomes in crop yields and profits are explained by profits allowing adaptation in the short-run by substitution.

Discussion

Summary

With any type of environmental degradation or shock, short-term and long-term adjustments allow adaptation to conditions. The type of adjustment depends on elasticities of land supply, transaction costs in shifting labour and capital and policy incentives. If supply is inelastic, transaction costs are high and policy incentives are driven to maintain the status quo, then necessary long-term adjustments can be delayed resulting in only partial recovery of land value in the long-run.

There are similarities between Hornbeck (2012) and Mendelson et al. (1994) in that they both examine the long run impact on land value and focus on adjustments involving land use. They both find that land values decrease with environmental degradation. While Hornbeck (2012) analyzes long-run adjustments in terms of the delayed effect of land-use substitution during the Dust Bowl era, Mendelson et al. (1994) explicitly argue that the ability to make such substitution can actually mitigate the negative impacts of environmental shocks.

There are a myriad of ways to measure environmental changes and shocks with specific reference to climate change, including temperature, precipitation, soil characteristics. While both short- and long-run adjustments are important, they are not mutually exclusive in that short term measures impact longer term ones and in many instances delay recovery and permanently suppress future asset prices. Hansen and Libecap (2003) determined that the small average size of farms hindered the short-term response and long-tern recovery. The also indicated that the Homestead Act limited the size of farms in the Great Plains which reduced the ability of farms to implement erosion controls on a sufficient scale. This implies that policy may have as much of an impact before any environmental shock as after.

Generally, the literature review produces the following salient points:

1. Policy decisions are important both before and after any environmental shock whether immediate or slow-acting. The impact of policy could delay recovery of environmental assets and reduce the recovery potential. The effect of economies of scale highlights the importance of policy design and evaluating their effectiveness. Well-intentioned policy, for example, protection of smaller agents, may very well be poorly designed.
2. The “Ricardian” approach postulates adjustment through substitution which takes into account general equilibrium effects not accounted for simply examining changes in value. However, other adjustments not discussed in this paper, can be significant, for example, emigration.
3. Due to the nature and scope of environmental data, the choice of outcome variables is critical, as well as the empirical technique. There are many factors which affect environmental outcomes and these can vary between geographic regions and across time. Therefore, it is crucial to control for these time and fixed effects. Environmental data on temperature, precipitation and soil erosion can shed light on time trends and spatial differences. Consequently, the D in D method seems both popular and particularly effective.

Significance

Climate Change is an urgent concern today. Any examination of historical environmental shocks gives an idea of what may come, what was done correctly and what was done poorly.

Policy implications are central to adjustments in that they can help or hinder effective action before and after an environmental shock or gradual degradation. The global scale and pervasiveness of climate change means that policy development must account for permanent loss of environmental capital in terms of reducing it and determining alternative adaptation.

Some types of adjustment were mentioned including changes in land value, substitution in use, substitution of factors, switching crops and emigration. While these may be feasible on a localized level, they may not on a global scale. Small islands cannot adjust by emigration and small economies cannot adjust due to scale. Small and geographically homogeneous countries cannot adjust by substitution.

Measurement of outcome variables like profits, value and rents are relatively easy when environmental assets are commercialized. However, some assets are more difficult to measure because there is an indirect benefit to preservation, for example, the Amazon Forest. This paper does not discuss this but it is important to determine a face value for such assets, especially when impacts are global and value is somewhat intangible.

Finally, economics tends to focus on average and aggregate events. However, this author feels that individual impacts should be treated as equally important, although these are not easy to explore and tend to be less examined.

Conclusion

One of the key findings of this review is that the effectiveness of any environmental mitigation is a function of time i.e. a delay in execution can result in a longer recovery period and lower future values of environmental assets. Agents may not implement mitigation measures not because climate change and other environmental degradation are unrecognized but because they are otherwise constrained to do so. Reasons for this include lack of access to capital, government policies that do not internalize long-run environmental costs, preference to short term profit maximization over long run protection, and lack of economies of scale regarding mitigation measures.

The nature of environmental panel data leads to the particular effectiveness of the D in D approach. When the right controls are used, treatment can be considered "as if" random. A geographic region, whether state or county, has particular long-term characteristics that should be controlled for in fixed effects. Weather variables like temperature and precipitation also vary by region but also over time and should be accounted for by inclusion of time effects. There are a number of outcome variables which can be used related to land value, rents and profits. In this case, the treatment assumed is the change in weather or climate from one period to the next.

Long-run adjustments are essential in mitigating the effects of any environmental shock or longer terms changes regarding climate. Economists have still not yet established consensus on the economic effects of climate change. However, this literature review suggests that delaying this adjustment can actually reduce the recovery value of environmental assets.

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