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ASSESSING THE CAPITAL COSTS OF MAXIMIZING SUSTAINABLE AGRICULTURAL PRODUCTION IN BRAZIL

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Summary

1. Introduction

Increasing agricultural productivity plays a key role in the efforts to combine agricultural growth and forest protection by allowing farmers to produce more using the same area.[1] However, for agricultural productivity to increase, farmers must invest considerable resources to be able to use modern inputs such as tractors and fertilizers.[2] Thus, evaluating the demand for capital that productivity increases would generate is important to understand which changes in the supply of agricultural credit are necessary to support increased agricultural production.

In this report, CPI explores municipality-level information on revenues, operating costs and farm equipment to quantify the costs of maximizing Brazil's agricultural production without increasing deforestation. It begins by measuring the potential to increase crop and beef output in each municipality of the country. It then combines this measure with information on operational costs and the value of farm equipment to estimate the increase in capital required to maximize crop and beef output in each municipality of the country.

The researchers find that Brazil could increase crop output by 79.0-104.5% without affecting deforestation. It could also increase beef output by 26.8% without increasing the area with pastures. To obtain these increases in production, farmers would need to increase the value of farm equipment by 47.5-51.6% (USD 34.4-37.4 billion) and the operational costs by 43.5-50.5% (USD 44.4-51.2 billion). There is substantial regional heterogeneity in these numbers with the more substantial increases concentrated in regions as diverse as the north of the state of Goiás or the Vale do Ribeira region in the states of Rio de Janeiro and São Paulo.

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[1] Climate Policy Initiative (2013). Production and Protection: A First Look at Key Challenges in Brazil. Available at: https://climatepolicyinitiative.org/wp-content/uploads/2013/12/Production-and-Protection-A-First-Look-at-Key-Challenges-in-Brazil.pdf.

[2] For one example of the relationship between agricultural growth and input use, see: Assunção, J., & Bragança, A. (2015). Technological Change and Deforestation: Evidence from the Brazilian Soybean Revolution. INPUT Working Paper. Available at https://www.inputbrasil.org/wp-content/uploads/2015/08/Technological_Change_and_Deforestation_Working_Paper_CPI.pdf.

2. Data and Methods

2.1. Data

Municipality-level information from the 2006 Agricultural Census is the main data source used in this project. This dataset has information on land use, revenues, costs and farm equipment. The main outcomes in the analysis are crop output, beef output, operating costs, and the value of farm equipment. Crop output is defined as the log of crop revenues; beef output is defined as the log of the number of cattle; operating costs is the sum of all costs incurred by farms including costs with wages, seeds, fertilizers, herbicides as well as other services farms often purchase; the value of farm equipment is the value of the all the vehicles, machines, and equipment the farm owns. All variables are reported in 2006 prices. We use the Índice de Preços ao Consumidor Amplo (IPCA) – the official inflation index in Brazil – to bring the values to prices of September 2018. We then convert the values to USD using the exchange rate of September's last business day (R$ 4.05 / 1 USD).

Information from the 2006 Agricultural Census is supplemented with geographic information collected from different sources. Information on the area available for farming is built from the Mapbiomas dataset. Information on soil types and agricultural suitability is collected from maps constructed by Embrapa. Information on rainfall and temperature comes from the Matsuura and Wilmott dataset.

2.2. Methods

Potential to Increase Output. To measure the potential to increase crop and beef output, it is necessary to infer the productivity (or production efficiency) in each municipality. The empirical exercises in this report use Stochastic Frontier Analysis (SFA) to estimate productivity. This method offers a flexible way of simultaneously estimating production function parameters and inferring production efficiency.

SFA is built on two hypotheses. First, it considers that the relationship between inputs and outputs can be described by a Cobb-Douglas function. Second, it posits that the distribution of shocks is bi-caudal (e.g., normally distributed) while the distribution of efficiency is mono-caudal (e.g., half-normally or exponentially distributed).

Efficiency is reported in a zero to one scale which reports the municipality's relative productivity in comparison to the most productive municipality in the country. It can be interpreted as an efficiency gap in the sense that it measures the fraction of the maximum output the municipality actually produces. This implies the potential to increase output is just the inverse of the efficiency level. For example, a municipality with a efficiency level of 0.7 would be able to increase output by a factor of $(0.7)^{-1} = 1.42$ using the same resources. Because closing the country-level efficiency gap might not be feasible, the potential to increase output is also computed under alternative scenarios in which only biome or state-specific gaps are eliminated. For this, efficiency levels are normalized with respect to the most efficient municipality of the biome (state).

Three different specifications are reported: (1) efficiency of crop production assuming that cropland is not fixed and farmers might convert pastures into cropland; (2) efficiency of crop production assuming that cropland is fixed; (3) estimates efficiency of beef production assuming the area with pastures is fixed. All models control for the available land for agriculture as well as for suitability, soil types, and climate. This ensures that potential increases in output for each municipality come from increases in productivity and not from increases in farmland.

Costs to Increase Output. Economic theory indicates that demand for inputs is a function of efficiency levels, input prices, and endowments (e.g., geographic characteristics). Therefore, it is possible to compute the additional capital farmers would require to maximize output by: (1) estimating the relationship between input use and the measure of efficiency derived from the Stochastic Frontier Analysis (SFA) models described earlier; (2) predicting the costs of eliminating inefficiencies in both crop and beef production. The focus is in two measures of input use: operating costs (wages, fertilizers, defensives, seeds etc.) and farm equipment (tractors, harvesters, seeders etc.).

The costs to maximize output are computed at the country, biome, and state levels in two different scenarios. The first uses the efficiency estimates derived from the model in which cropland is not fixed. The second uses the efficiency estimates derived from the model in which cropland is fixed.

3. Results

3.1. Potential to Increase Output

Figure 1 reports the potential to increase crop output. Eliminating country-level inefficiencies in the model with pasture to cropland conversion (P2C) would increase crop output in 104.5%. This number decreases to 79.0% in the model without pasture to cropland conversion (P2C). This indicates that about one quarter of the output growth coming from eliminating inefficiencies occurs through conversion of low productivity pastures into high productivity cropland. **However, three quarters of the growth comes from increases in the productivity of the existing cropland.**

Eliminating biome-level (state-level) inefficiency gaps in the model with P2C generates output increases of 58.6% (49.1%). This is about half of the gain obtained from eliminating country-level inefficiency gaps. Closing these gaps in the model without P2C generates increases in output of 51.7% (46.0%). **These figures indicate the importance of reallocation of land from low productivity pastures to high productivity cropland is less important at the biome-level (state-level) than at the country-level.**

Figure 2 reports the potential to increase beef output. Eliminating inefficiencies in beef production generates much smaller gains than in crop production. Eliminating country-level inefficiencies generates gains close to 30%, biome-level gains close to 20%, and state-level gains close to 15%. **In general, this indicates that productivity in cattle ranching is more homogeneous throughout the country than productivity in crop cultivation.**

Figure 3 presents the distribution of the output increases across municipalities. Panels A-F present the gains in the different models. Output increases are considerably lower in the biome-level and state-level scenarios than in the country-level scenario. The largest increases are typically concentrated in regions as diverse as the center-north of Minas Gerais, the north of Goiás, the northwest of Mato Grosso do Sul, or the south of Pará.

Figure 4 presents the spatial distribution of the gains in beef production throughout the country. The dispersion is not very large across the country. Nevertheless, eliminating inefficiencies would generate large increases in beef output on the border of the states of Maranhão, Piauí and Tocantins and on the border of the states of Pernambuco and Bahia in all scenarios considered.

3.2. Potential to Increase Output

Figure 5 depicts the bivariate relationship between input use and the efficiency levels in crop production. Panel A presents the relationship for the log of the value of farm equipment and Panel B for the log of expenditures. In both cases, there is a positive relationship between efficiency and input use. The relationship is concave, being steeper for low efficiency levels (below 0.5) and flatter for high efficiency levels (above 0.5). Figure 6 presents the same relationship for efficiency in beef production. Again, there is a positive relationship between efficiency and input use. However, the relationship does not flatten for high efficiency levels as the relationship between input use and efficiency in crop production.

Because the relationships are similar and there is more dispersion in crop output, the estimates of the cost of maximizing beef and crop output will use only information on crop efficiency. Implicitly, this assumes that input use is driven by crop production and not by beef production. Estimates using both measures are similar on average, but have more outliers.

Table 1 depicts the increases in farm equipment required to maximize agricultural output. These increases range from 31.2% to 51.6% of the current value of the farm equipment. This is the equivalent of adding USD

22.6-37.4 billion to the stock of farm equipment. Table 2 shows the increases in operational costs required to maximize agricultural output. These increases range from 29.4% to 50.56% of the current operational costs. This is the equivalent of adding USD 29.8-51.2 billion to the operational costs of the country's farms.

3.3. Discussion

What is the interpretation of these numbers? Consider the numbers for the state-level scenarios in the model without pasture to cropland conversion. The findings indicate that an increase in crop output of about 46% and an increase in beef output of 14.1% (the numbers from eliminating inefficiencies at the state-level) would require an increase in farm equipment and operational costs of about 30%. It is important to emphasize that these numbers represent requirements. There are no guarantees that capital injections would generate an increases in production. For this to occur, the financial system would have to distribute and farmers would have to use the additional capital efficiently. However, there are a number of government and market failures that might keep this from occurring. Thus, what the numbers reported above mean is that at least this amount of capital is necessary to maximize agricultural production in Brazil.

4. Conclusion, Limitations, and Next Steps

In this report, CPI explores municipality-level information from the 2006 Agricultural Census to quantify the costs of maximizing Brazil's agricultural production without increasing deforestation. It begins by measuring the potential to increase crop and beef output in each municipality of the country. It then combines this measure with information on operational costs and the value of farm equipment to estimate the increase in capital required to maximize crop and beef output in each municipality of the country. It shows that crop (beef) output might increase up to 104.5% (26.8%) without increasing deforestation. Nevertheless, maximizing agricultural production would require increases in capital use. Farms' operational costs would have to increase at least USD 37 billion and the value of farm equipment at least USD 52.2 billion.

One limitation of the current work is that the data from the 2017 Agricultural Census has not yet been published. This restricts the analysis to data from the 2006 Agricultural Census, and implies that the numbers from this report are not capturing the changes that occurred in the country's agriculture over the past decade. Updating this work using data from the 2017 Agricultural Census would be important to analyze whether these changes affect the estimates of the capital necessary to maximize sustainable agricultural production in Brazil.

Another caveat to note in the estimates from this report is that it does not distinguish whether capital is being used in beef or crop production. Updating this work using (restricted access) farm-level data would be important to examine how capital use changes with productivity in different agricultural activities.

CPI is currently working on advancing its research agenda in both directions. A proposal to access farm-level data from the Agricultural Census for all available years has been submitted a proposal to IBGE (the national statistics bureau). The proposal will likely be considered in the first semester of 2019, coinciding with the release of the 2017 Agricultural Census.

Figure 1: Potential to Increase Crop Output

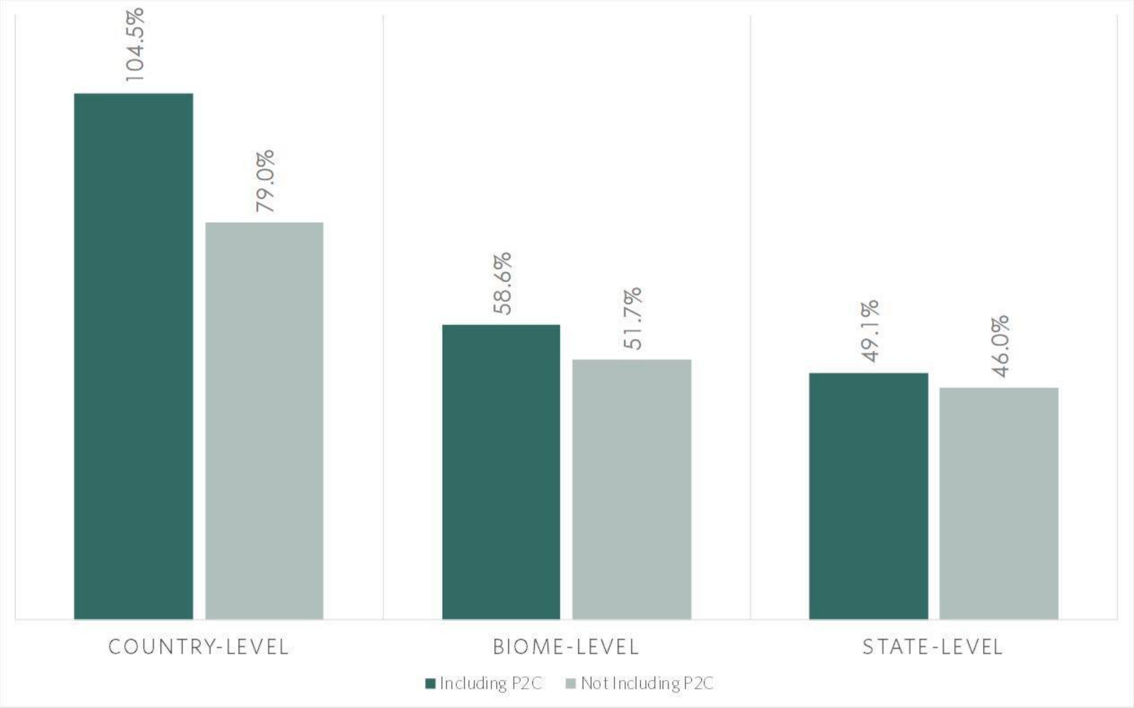


Figure 2: Potential to Increase Cattle Output

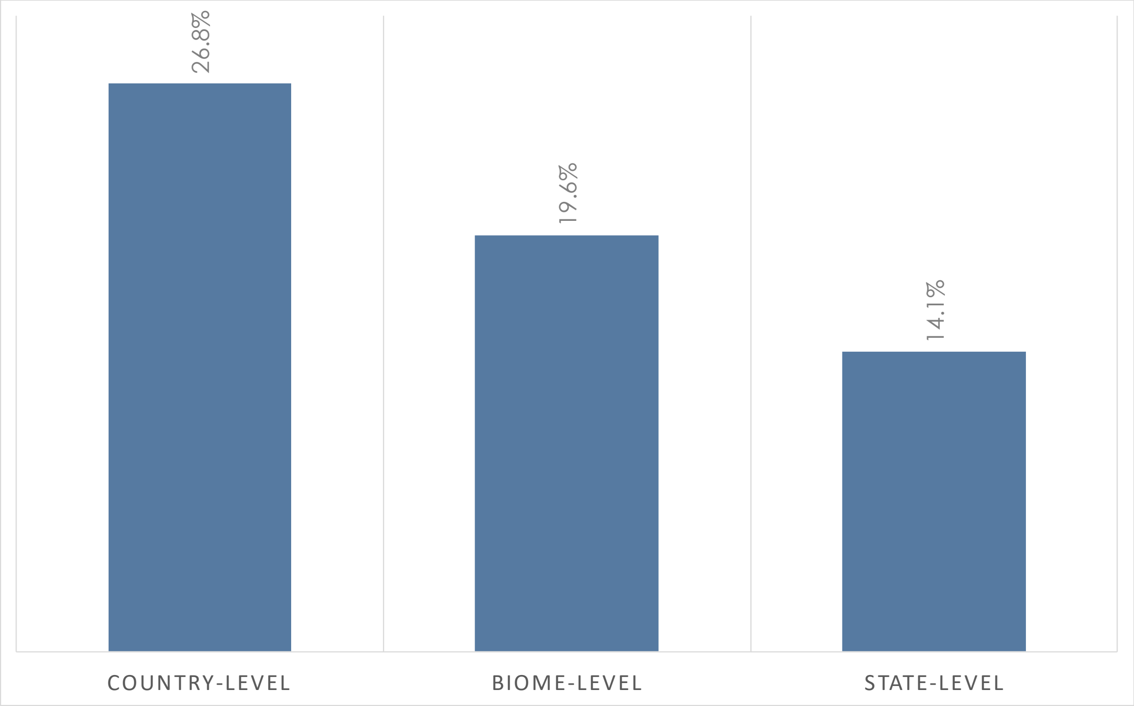
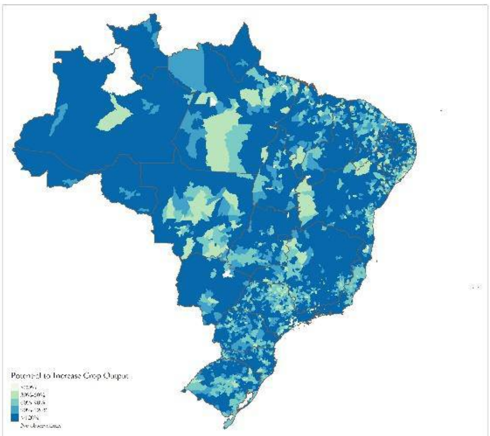
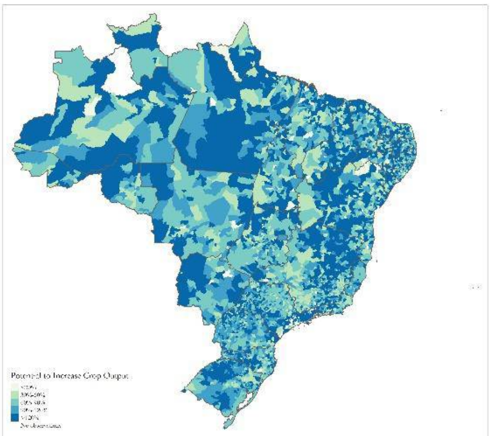


Figure 3: Spatial Distribution – Potential to Increase Crop Production

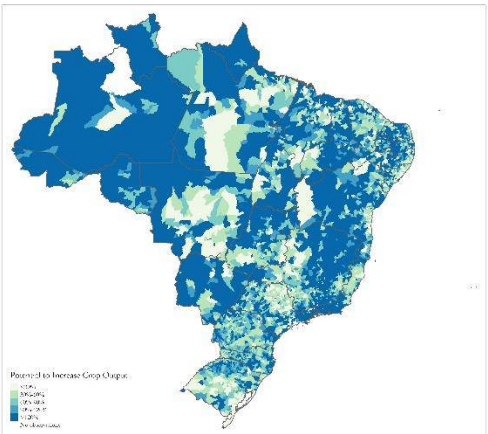
Panel A: Country-Level + Including P2C



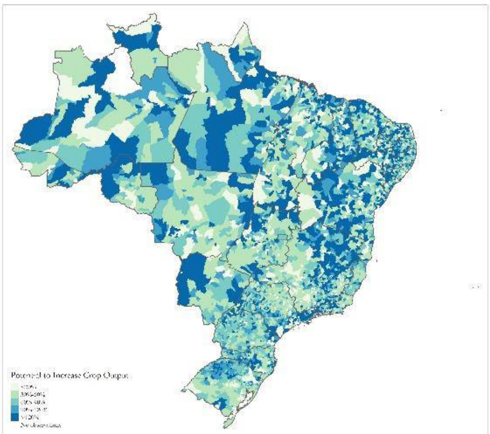
Panel B: Country-Level + No P2C



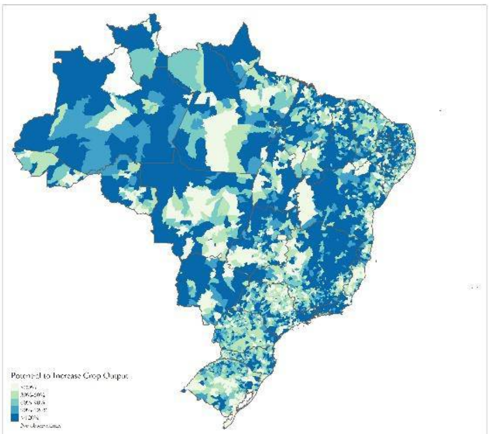
Panel C: Biome-Level + Including P2C



Panel D: Biome-Level + No P2C



Panel E: State-Level + Including P2C



Panel F: State-Level + No P2C

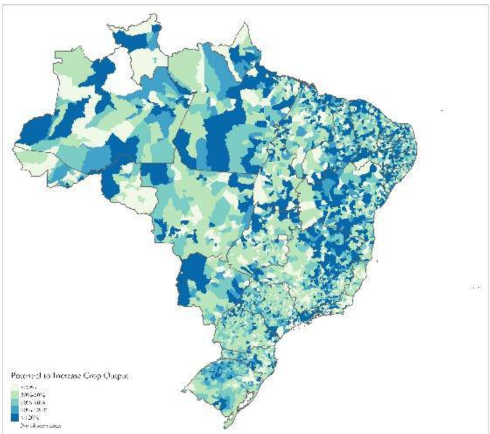
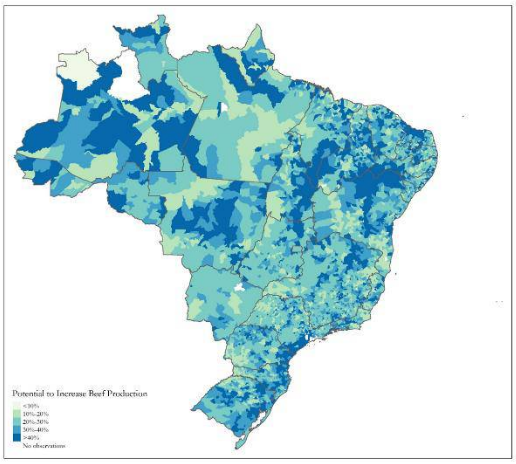
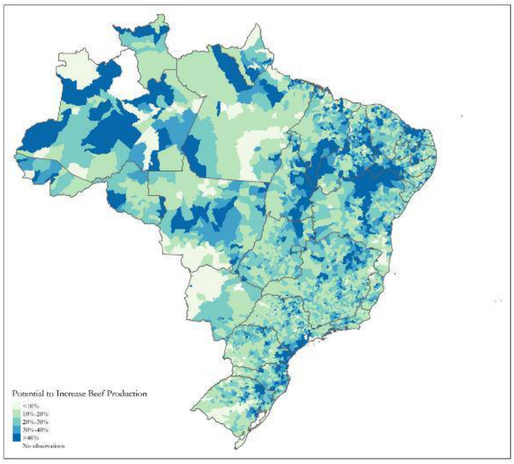


Figure 4: Spatial Distribution – Potential to Increase Beef Output

Panel A: Country Level



Panel B: Biome-Level



Panel C: State-Level

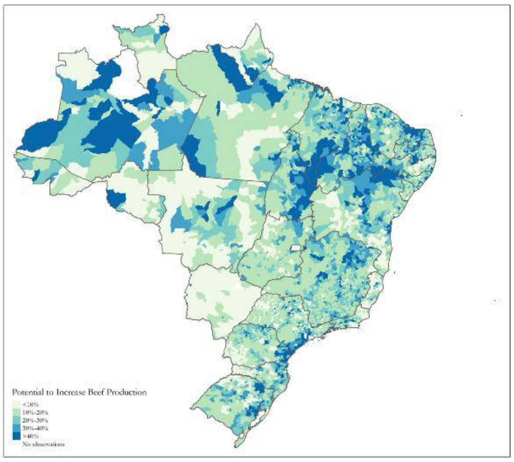
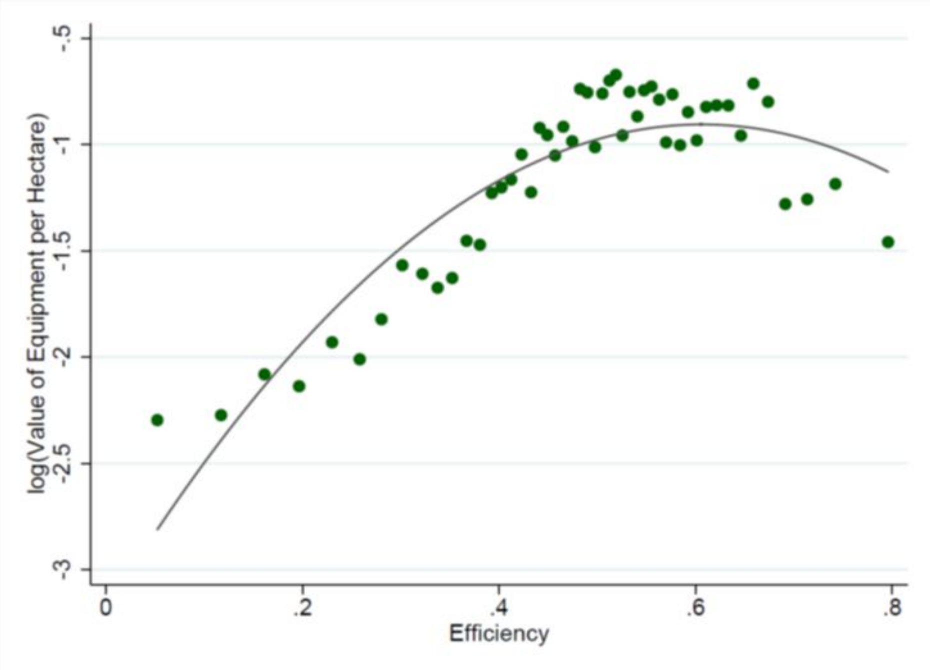


Figure 5: Efficiency in Crop Production and Input Use

Panel A: Value of Equipment



Panel B: Expenditures

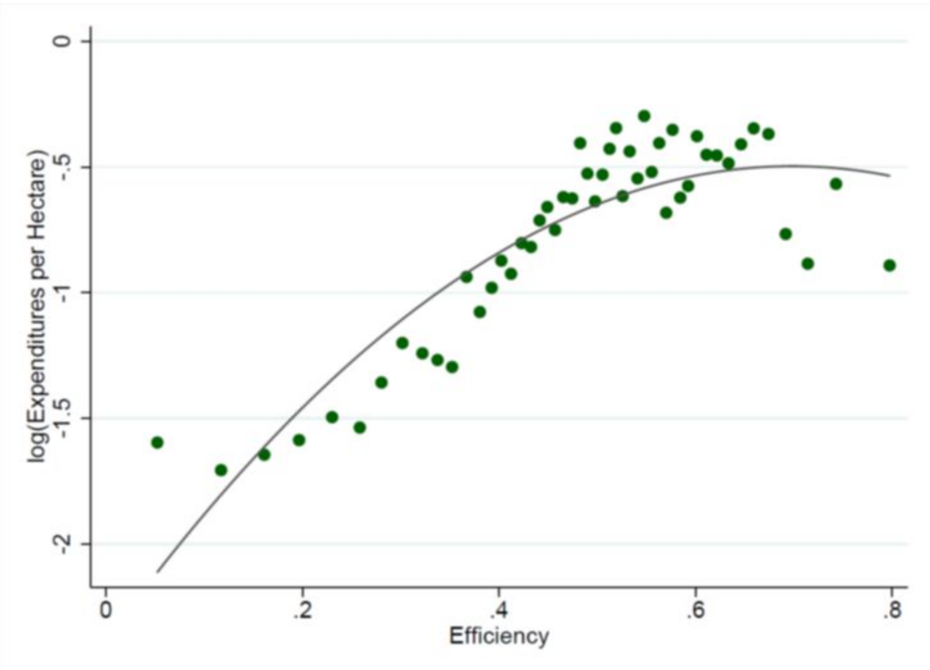
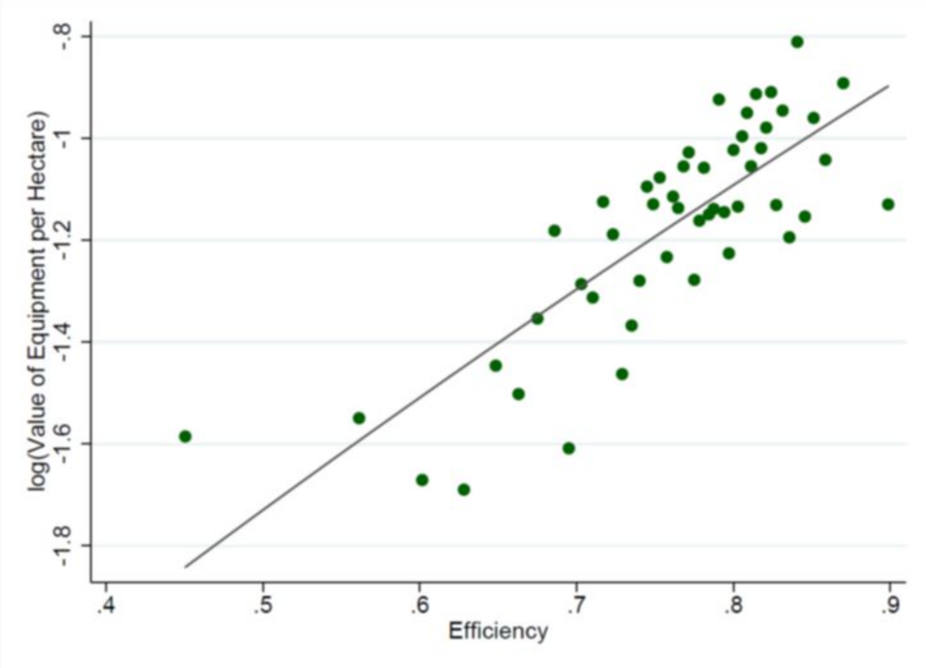


Figure 6: Efficiency in Crop Production and Input Use

Panel A: Value of Equipment



Panel B: Expenditures

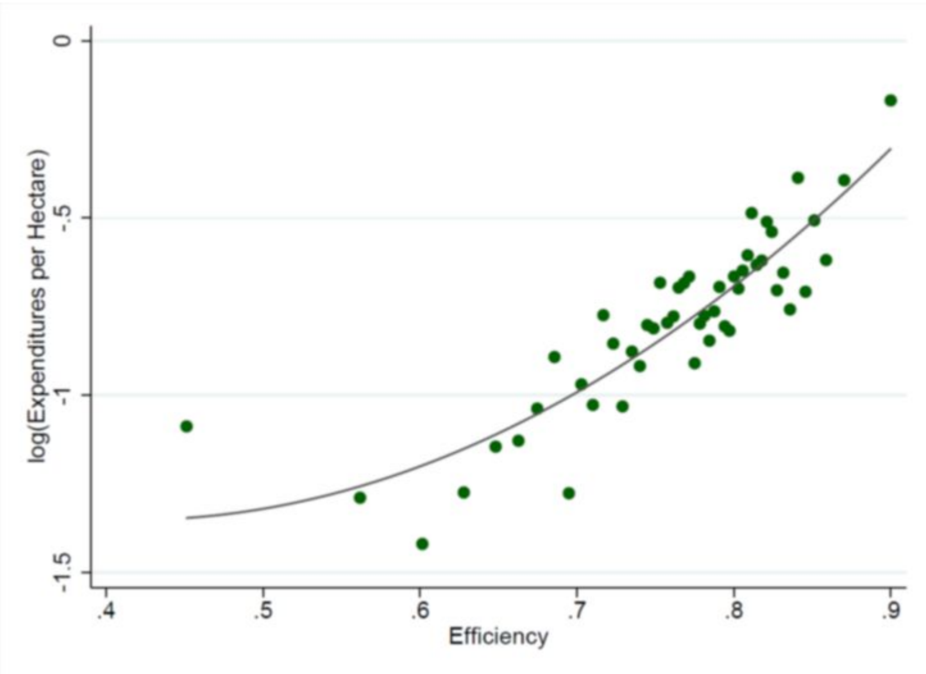


Table 1: Value of Farm Equipment

	Country-Level (1)	Biome-Level (2)	State-Level (3)
Value of Farm Equipment (US$)	72,391,265	72,391,265	72,391,265
Requirement to maximize output			
Including P2C	37,351,705 51.6%	25,722,727 35.5%	22,557,573 31.2%
Not Including P2C	34,381,641 47.5%	25,092,019 34.7%	22,800,011 31.5%

Table 2: Total Expenditures

	Country-Level (1)	Biome-Level (2)	State-Level (3)
Total Expenditures (US$)	101,423,319	101,423,319	101,423,319
Requirement to maximize output			
Including P2C	51,190,954 50.5%	35,256,339 34.8%	31,705,309 31.3%
Not Including P2C	44,355,694 43.7%	32,181,473 31.7%	29,813,598 29.4%