The Impact of New World Crops on the Indian Economy

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Abstract

Christopher Columbus's expedition opened new trade routes between the New and the Old World. One of the consequences of this expanded trade is the introduction of new crops to the Old World, which function as a new agricultural technology since the new crops were often more nutritious and productive than existing crops. This study seek to answer whether an agricultural productivity shock of this form is sufficient to increase both population and economic growth in India. I find that the introduction of maize in India significantly increase population growth and growth in urbanization. This suggests that the introduction of a New World crop is sufficient to spur modern economic growth.

1 Introduction

Following the exploration of Christopher Columbus, trade opened between the New and the Old Worlds. This "Columbian Exchange" facilitated the movement of both people and crops across the Atlantic Ocean. Much of the focus on this exchange has focused on Europe and the Americas, but these newly opened trade routes had effects elsewhere as well. One of the important effects of the Columbian Exchange was the introduction of new crops. Often the crops from the New World were more nutritious and more productive than their counterparts from the Old World and soon became staples in the diets of the Old World.

Around this same time world population grew rapidly. There were under 300 million people globally in 1000 CE. By 1900 population had grown to 1.6 billion (**Nunn2011**). Some have attributed a portion of this rapid growth in population to the introduction of these New World Crops (eg. **Langer1963**; **McNeill1949**). The evidence for this has been borne out by empirical research as well (**Nunn2011**; **Chen2016**; **Cherniwchan2019**). Whether or not the new crops contributed to economic growth is still unclear.

In this paper, I test whether the introduction of a New World crop, maize, to India is sufficient to spur economic growth as well as population growth. The introduction of the New World crops create an agricultural productivity shock since they were more productive and nutritious than the existing crops. I focus on maize in this paper because of its suitability to become a staple crop as well as the timing of its introduction. The effect on population follows from a straightforward Malthusian process: the greater yield and calories means that a greater population can be supported with the same amount of cultivated land. The effect on economic growth is not as direct. If the New World crops are productive enough, then sufficient food can be produced with fewer resources, including both land and labor. This frees some labor to work in more productive sectors spurring economic growth. Other studies have examined these and similar questions for other geographies, but the evidence for the sufficiency of a New World crop increasing economic growth has been mixed.

To estimate the impacts of maize on the Indian economy I exploit variation in the suitability of growing conditions for maize in India. Since India is a large country with varying geography and climates, there exist differences in the suitability of the crop land for maize. Using the timing of introduction of maize to India I test if greater suitability increases population density and economic growth, as measured by urbanization. If the maize does increase both population and economic growth it is more likely to do so in the regions where the growing conditions for maize are more favorable.

Using these sources of variation, I estimate two different specifications. The first specification is a panel difference-in-differences specification. This compares outcomes from states with more suitable conditions for growing maize to the outcomes of states with less suitable conditions for growing maize, before and after maize was introduced to the sub-continent. This specification controls for time-invariant state characteristics, as well as country wide trends. The second specification builds upon the first by including spatial lags of the dependent variable as additional regressors. This model allows for me to control for spatial dependencies between states such as agglomeration and population spillovers that may otherwise confound the growth effects of the introduction of maize. I use a panel of data on Indian states from 1400 to 1800 which contain information on population and urbanization levels, the suitability of maize as a crop, and other state characteristics.

Using the simple difference-indifferences specification, I find that the introduction of maize does significantly increase urbanization of states in India. Using the preferred set of estimates which controls for differential trends in contact with Europeans and climate, I find that a 1% increases in the suitability index for growing maize increases urbanization by 0.00446%. This implies that the introduction of maize was responsible for about 8% of the growth in urbanization during the sample period. This specification, however, does not find any significant impacts from the introduction of maize on population density. When accounting for the spatial spillovers for growth, I find more evidence that the introduction of maize does positively impact the Indian economy. A 1% increase in the suitability for growing maize increases population density by 0.0244% and urbanization by 0.0036%. These results imply that the introduction of maize significantly impacted the pre-colonial Indian economy. The introduction of maize accounted for about 8% of population growth and about 8% of the growth in urbanization.

This work contributes to a growing strain of literature examining the effects of New World crops that were introduced via the Columbian Exchange. The introduction of the potato to Europe has been shown to contribute to both increased population density and economic growth (**Nunn2011**). **JustinCook2014a** builds on the work of **Nunn2011**, and shows that areas with more milk consumption with potatoes is what increases density and economic growth opposed to just potatoes. The adoption of clover in Denmark also contributed to its growth, both in population and economic growth (**DallSchmidt2018**). The effects of a new crop on economic growth are not universal; other studies have found that the introduction of New World crops only contribute to increased population density. **Chen2016** and **Cherniwchan2019** find this for China and Africa, respectively. By focusing on India, I will be providing further evidence whether the introduction of a New World Crop is sufficient to increase both population and economic growth.

This paper also helps explain the differences in growth between Europe and Asia before 1800 know as the Great Divergence. Before 1800, historians claim that Europe and Asia were similarly developed because the grain wages were similar (**Broadberry2006**). **Broadberry2006** show that the divergence began earlier. This difference in responses to the introduction of a New World crop in Europe and China may help explain why the two regions' fortunes diverged. **Voigtlander2013** claim that another reason for the Great Divergence is due to the plague and the nearly constant wars. The plague reduced population which applied upward pressure on real wages, and the lack of unified political structure led to wars which also led to increased wages. The wages stayed high even as population grew. The introduction of a New World crop may have also contributed to these trends.

I also contribute to the literature on the determinants of urbanization. How a location transitions from rural to urban depends of the suitability of the land for crop cultivation, seasonal frosts, access to waterways, and lower elevations (**Motamed2014**). The same study then looks at the equivalent modern countries and finds that earlier urbanization is associated with higher per capita incomes. The geographic features of a location are also important determinants of urbanization. **Bosker2017** find that "first nature" characteristics such as natural resources, agricultural potential, transportation potential, and defensive advantages, are important seeds for city growth. They also find that proximity to other urban centers, or "second nature geography" is also an important determinant of urbanization; a location may have excellent first center geography but without sufficient second nature geography characteristics those locations do not become urban centers (**Bosker2017**). Many present day urban areas are located where fall line portages existed (**Bleakley2012**; **Bleakley2015**) despite portages being no longer necessary. This shows that where urban centers first develop continue to be urbanized areas in modern times, so focusing on whether maize suitability contributes to historical urbanization can help explain present urbanization.

The remainder of the paper proceeds as follows. Section 2 provides the historical setting around the time of the introduction of maize. Section 3 discusses the choice of maize. Section 4 outlines the data and methodology used for analysis. Section 5 presents the results, and Section 6 concludes.

2 History of the Indian Economy

The Pre-Colonial Indian economy was defined by small-scale farmers. Land and labor were abundant, but land was not bought and sold as a commodity during this period (**Rothermund1988**). However, the number of people available to work the land was greater than quantity of suitable crop land. This led to a fuedual-like system where landlords taxed the output of the peasant farmers who tilled the land, keeping some for themselves and paying patronage to the local lord with the rest (**Rothermund1988**). This system of extraction remained decentralized because of the lack of monetization which increased the cost of transportation.

This system remained unchanged until the beginning of the Mughal Empire in the 1500s near Delhi. The Mughals were a warring state and were preoccupied with attacking their neighbors and expanding their empire (**Richards2003**). Their efforts were largely successful because they had the superior military technology of horses (**Rothermund1988**) which allowed them to overpower the local lords. By 1690, the Mughals had expanded their empire to cover most of the subcontinent and had approximately 100 million people living in those lands (**Richards2003**).

The Mughals brought centralization and standardization to the local tax system, facilitating the movement of people, money, goods, and information. The emperor would place trusted officers in local villages to oversee the collection of the land tax (**Richards2003**). This led to new urban centers in the countryside to be established and act as trading and tax collection hubs (**Rothermund1988**). Along with centralization, came increased costs of maintaining the empire-wide tax collection system. This required increased taxes and caused an increase in the amount of land that was cultivated to produce more crops, so the peasants working the land could afford the taxes levied on them (**Richards2003**).

Markets remained fragmented, however. Only lightweight, expensive goods were transported long distances due to the lack of adequate roads and reliance on pack animals. All other goods were traded locally (**Rothermund1988**). This meant that taxes needed to be paid in silver imperial coin (**Richards2003**). Silver was not produced within the empire, so it needed to be imported from abroad. This led to increased trade with Europeans who had a high demand for Indian goods (**Rothermund1988**). Though there was a large population, its absorptive capacity was not great enough to prevent inflation from increasing (**Rothermund1988**). Inflationary pressures meant that peasants needed to cultivate more land and produce more agricultural crops to be able to afford the land tax to which they were still subjected (**Rothermund1988**; **Richards2003**). Eventually, the system fell apart as taxes rose. Peasants could not benefit from higher prices because of the lack of integrated markets, so they were subject to only local prices which were not high enough to afford the high taxes and maintain their subsistence (**Rothermund1988**). The Mughal Empire eventually ended in the mid-1800s.

The introduction of New World crops may have been an important innovation given this backdrop. If the new crops were more productive, the required amount of grain could be produced with fewer inputs, making the payment of taxes easier for the peasants. This history also outline other factors such as the expansion of the Mughal Empire and trade with Europeans that must be accounted for in the empirical analysis.

3 Suitability of Maize

For a New World crop to possibly be the reason for increased population density and urbanization it needs to be widely adopted and more nutritious than the existing crops. Maize was not the only crop to make it to India, but it is the most likely to have become a dietary staple.

Nunn2010 highlight that capsicum peppers from the New World were first introduced to India around 1542. While capsicum peppers are high in vitamin A, B, and C, these peppers are not eaten in large enough quantities for them to cause an agricultural productivity shock. This is helpful for understanding the timing of when a potential new staple crop was introduced, however.

One potential crop highlighted by the previous research was the white potato. This crop was first introduced to India by Europeans, and the first recorded mention of the potato is from 1615 (**Mazumdar1999**). While the timing of this crop is right, the potato was generally a supplement to the Indian diet,and thus, spread slowly not gaining widespread adoption until the late 18^{th} century (**Nunn2011**). Maize, on the other hand, did have widespread adoption in precolonial India and became a dietary staple (**Mazumdar1999**). Given the other evidence for when New World crops were first introduced to India, one can assume that maize was introduced around the same time.

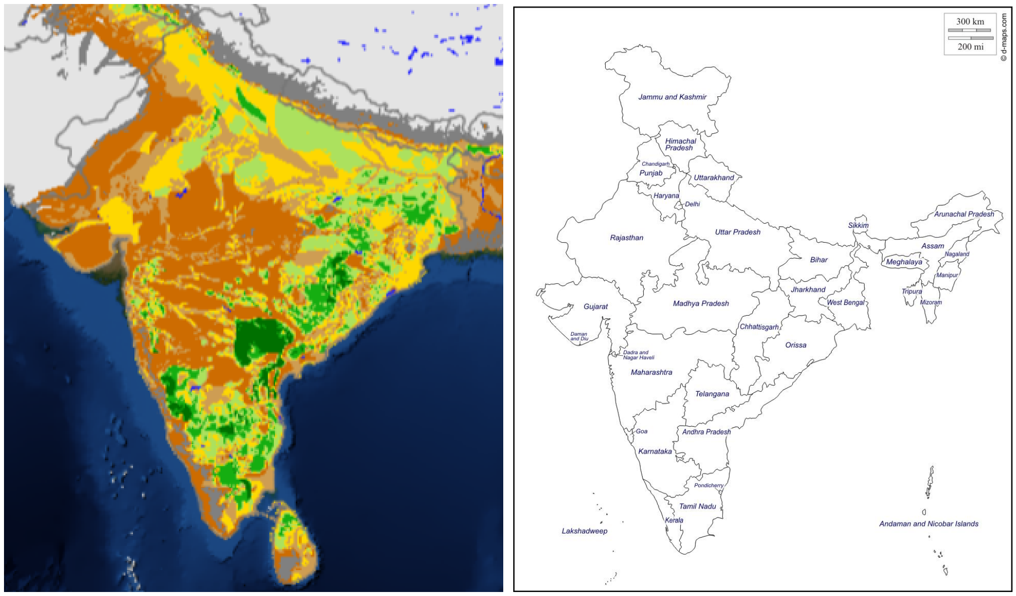
Table 1: Annual Crop Yields of Various Staple Crops

Crop	Yield (kg/ha)	Energy (MJ/ha)
Millet-Sorghum	1200	17,800
Maize	1700	26,000
Cassava	4000	26,8000
Sweet Potatoes	8000	28,800
White Potatoes	4400	14,200

Source: **Cherniwchan2019**

For there to be an agricultural productivity shock the new crop must be more nutritious per area of land than the existing crops. Prior to the adoption of the New World crops, Indians subsisted on millet and sorghum (**Mazumdar1999**). The table from **Cherniwchan2019** shows the yield of several New World crops per hectare as well as the nutritional value

Figure 1: Suitability of Maize and Indian States



Source: FAO-GAEZ   Source: https://maps-india-in.com

per hectare, compared to millet and sorghum. All of the New World crops are much more nutritious per hectare than either millet and sorghum. This combined with the timing of introduction and adoption of the crops suggests that maize is the most likely candidate to have caused an agricultural productivity shock in India.

4 Data and Methodology

4.1 Identification

I use the suitability index for maize since I do not have historical maize production data. As shown in Figure 1, there is significant variation in the suitability of growing conditions for maize. The figure divides suitability into eight possible categories, from "Very High", in dark green, to "Not Suitable" in light grey. These categories reflect differences in the potential capacity of land to produce maize at the maximum yield due to differences in geographical, soil and climatic conditions. These differences create variation which can used to identify the effects of maize; average outcomes can be compared from places where it is highly suitable (such as parts Telangana) with average outcomes from locations where it is not (such as Gujarat and Madhya Pradesh).

The second source of variation comes from changes in the availability of maize over time. As previously discussed, I am not able to observe the exact time of introduction of maize for every state. Maize was first introduced around the same time as potatoes in 1615, after which it spread quickly throughout the country. Since I am not able to observe the introduction of maize for each individual state I treat the introduction as a common shock to all states. I exploit this temporal variation by comparing average outcomes before and after maize was introduced to India.

I identify the effects of the introduction of maize on both population density and economic growth by exploiting these two sources of variation using difference in differences. Since I am not able to observe economic growth directly I proxy for economic growth with urbanization. This approach compares the average population densities of, or the average urbanization of states where land was suitable for adopting maize with the same outcomes for states where adoption was not possible due to lack of suitable land. This allows me to control for a number of time-invariant factors, such as a state's geographic characteristics and advantages, and trends common to all states, such as ongoing technological change that would otherwise confound identification.

This idea rests on the fact that maize was only suitable as a crop in a subset of states. This means that, while it was potentially available everywhere in India after its introduction, maize could only be adopted in places where it could be grown due to exogenous factors. While all states may have tried to adopt maize once it was introduced due to factors such as existing population pressures, adoption was not possible everywhere due to geography. Since the ability of the land to grow maize was not known prior to introduction, this rules out the possibility that my estimates are capturing existing effects rather than the effect of maize.

4.2 Data

This research design requires cross-state data on the suitability of maize. I follow an approach similar to **Nunn2011** and **Cherniwchan2019** and use a measure of suitability from the FAO-GAEZ data. I use the average land suitability index for growing maize by state under low-input productivity and rain irrigation conditions. The conditions best reflect the agricultural technology available in India during the periods of interest.

This research also requires data on population density and urbanization before and after the introduction of maize. I create these variables from the data contained in the History Database of the Global Environment version 3.1 . These data contain information on land use for the past 12,000 years including estimates for total population and population living in urban areas. These data are available at the five minute grid-cell. I aggregate these data up to the Indian state level for each state. For the grid-cells that intersect borders, I weight the estimates by the proportion of the grid-cell in each state. To obtain population density, I divide the aggregated population by the total land area of each state. Urbanization is calculated by taking the aggregated urban population and dividing by the total population.

Combining these data sources yields the two main panels of data utilized in the analysis: one for maize suitability and population density and one for maize suitability and urbanization. I focus the period of analysis to the time period immediately surrounding the introduction of maize: 1400-1800. The data is available by century from 1400-1700 and then by half century thereafter.

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Maize Suitability	198	31.52	17.61	1	57
Population Density	198	50.89	64.48	0.577	415.5
Urbanization	198	0.0634	0.0476	0	0.337

Table 2

4.3 Empirical Specification

I implement the above research design by estimating the following specification:

$$Y_{it} = \beta_0 + \beta_1[Maize_i \times post_t] + X_{it}\Gamma + \eta_i + \lambda_t + \epsilon_{it}$$

where Y_{it} is either the natural log of population density or the natural log of 1 plus urbanization in state i at period t. Each state's treatment is captured by $Maize_i \times post_t$, which is the natural log of maize suitability multiplied by a post-introduction indicator variable. The post-introduction indicator is equal to 1 if the time period is later than 1615 and 0 otherwise because the available evidence suggests that maize was adopted widely in India around this time. X_{it} are additional controls that capture other factors that may have impacted the adoption of maize such as contact with Europeans, climate conditions, and expansion of the Mughal Empire. η_i are the state fixed effects designed to capture the unobserved, time-invariant factors that may affect population density and urbanization, and λ_t are the period specific fixed effects that capture aggregate shocks that are common to all states. μ_{it} is an error term that captures idiosyncratic changes in either population density, or urbanization.

The coefficient of interest is β, which captures the effect of the introduction of maize on each outcome. When examining population density $\hat{\beta}_1$ should be positive. This is consistent with Malthus's theory on population: new technology will increase output and the increased output will lead to greater population growth. When urbanization is the outcome of interest, if the introduction of maize is sufficient to induce economic growth, $\hat{\beta}$ should also be positive since urbanization is closely related to economic growth. If it is not sufficient, then I would expect $\hat{\beta}_1$ to not be statistically significant.

The effects of the introduction of maize may not be isolated within a state's borders. The economic growth of one state may impact the growth of states nearby. Patterns of trade and regional agglomeration are two possible factors that may impact the adoption of maize and economic growth in states. To account for these spatial spillovers, I also implement a spatial lag model as a second specification:

$$Y_{it} = \beta_0 + \beta_1[Maize_i \times post_t] + X_{it}\Gamma + W\ Y_{-it} + \eta_i + \lambda_t + \epsilon_{it}$$

This specification is the same as above with the addition of $W\ Y{-it}$. This is the dependent variable of all other states $(-i)$ weighted by a spatial weighting matrix W. I implement a contiguity weighting matrix such that the each of a states neighbor with which it shares a border receive a weight of 1, and all other states with which it does not share a border receive a weight of 0. This weighting scheme is used instead of others because of the great size of the Indian sub-continent and many of the states are also geographically large. Therefore, it is more likely that a state's immediate neighbors have a greater influence on its own growth than another state that is much farther away.

5 Results

5.1 Baseline Results

Table 3 presents the results from estimating the effect of the introduction of maize on economic growth in precolonial India. Each panel of the table presents a different aspect of economic growth: Panel A presents the results for population density, and Panel B presents the results for urbanization. The first specification, in column 1 of each panel, includes no controls other than period and state fixed effects. This specification controls for time-invariant cross-state differences such as geography, and country-wide trends, such as technological change that may have affected the introduction and adoption of maize. The second specification in column 2, adds the natural log of the distance from the center of the state to India's border or coast, whichever is closer, interacted with the period fixed effects to account for differential trends in potential contact with Europeans. Column 3 adds the natural log of distance from the equator and elevation, two key factors in determining climate, interacted with period fixed effects to account for differential climate trends across states. Standard errors are clustered at the state level.

Panel A of Table 3 reports the estimates of the effects of the introduction of maize on population density. Column 1 indicates that a 1 percent increase in the a state's suitability conditions for growing maize increases population density by 0.0296 percent. This result is in line with the estimate of the introduction of maize in Africa found by **Cherniwchan2019**. These results are sensitive to including controls, however. Column 2 adds a control for potential European contact and the effect of the introduction of maize on population density increases 0.0360 percent, and column 3 adds controls for climate which reduces the estimate to 0.0131 percent and it is no longer statistically significant.

Panel B of Table 3 presents the estimates of the the effect of the introduction of maize on urbanization. The estimates for these specifications are also sensitive to the inclusion of controls. I find a negative, albeit insignificant, effect of the introduction of maize on urbanization in both columns 1 and 2. Once I include all of the controls for European contact and climate, I do find a positive and significant effect on urbanization from the introduction of maize. Increasing the suitability for growing maize by 1 percent increases the amount of urbanization in a state by 0.00446 percent. Given how sensitive both sets of specifications are to the inclusion of controls, the specifications in column 3 are my preferred set of estimates.

Table 3: The Effect of the Introduction of Maize on Economic Growth

	(1)	(2)	(3)
Panel A: Population Density			
ln(Maize)xPost	0.0296*	0.0360**	0.0131
	(0.0152)	(0.0165)	(0.0161)
EuropeanContact		X	X
Climate			X
adjustedR2	0.970	0.971	0.980
Panel B: Urbanization			
ln(Maize)xPost	-0.00101	-0.000868	0.00446***
	(0.00116)	(0.00167)	(0.00157)
EuropeanContact		X	X
Climate			X
adjustedR2	0.192	0.258	0.552

Table reports the estimates of the effect of maize on population density and urbanization. Panel A reports the results from the regression of the natural log of population density (people/km^2) regressed on the natural log of maize suitability interacted with an indicator for post maize introduction and other controls. Panel B reports the results from the regression of the natural log of urbanization (urban population/total population) regressed on the natural log of maize suitability interacted with an indicator for post maize introduction and other controls. All control variable are interacted with the full set of period fixed effects. The post maize introduction variable takes the value of 1 for any period after 1615. All regressions include state and period fixed effects. Standard are clustered at the state level and reported in parentheses. * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$

The estimates reported in Panel B of Table 3 provide some support for the introduction of maize impacting urbanization in India. However, from this estimate it is unclear how economically significant this result it. To better understand how meaningful this estimate is, I determine how much of the growth of urbanization can be attributed to maize for the average Indian state. I obtain the amount of urbanization attributable to maize by multiplying the estimate from column 3 of Panel B (0.00446) by the mean level of the measure for maize suitability (3.15). This calculation indicates that maize increased the level of urbanization in the average state by about 1.4 percent. Based on the data, the average state had share of total population living in urban areas of 0.07 in 1600, before maize was introduced, and the urban share was 0.06 in 1800 at the end of the sample period. This suggests that the urban share of the population grew by over 16%. Therefore around 8% of the total growth in the share of the urban population is due to maize. Altogether, the results in Table 3 show that maize did impact urbanization but not population density. This is suggestive that the introduction of maize allowed for some of the agricultural population to move to urban areas.

5.2 Alternative Explanations

The previous results show that the introduction of maize did not affect population density, but it did significantly impact urbanization. These baseline results may be capturing the effect of other factors. I first test whether these estimates are capturing the effect of other crops that may are important for the Indian diet. Second, I test whether the baseline estimates are capturing the effect of the expansion of the Mughal Empire, as its expansion may also determine population density and urbanization.

To test whether the baseline estimates are capturing the effect of other staple crops, I create similar measures as the $ln(Maize) \times Post$ for the white potato and for rice. The white potato is also a New World crop that was introduced around the same time as maize. I construct a measure the same way for the white potato as I do for maize, by taking the natural log of the state average growing suitability conditions for the white potato and interacting it with an indicator for periods later than 1650. The measure for rice is constructed slightly differently because rice was first cultivated in India much earlier than the sample period and is a staple crop in the Indian diet. For both of these reasons, I interact the natural log of the state average rice suitability conditions with the natural log of maize suitability and with the indicator for the introduction of maize. This construction treats maize as a supplemental crop, which may fit with the long history of rice in India.

The results of the alternative crop measures are presented in Table 4. For easy comparison, the first column re-presents the baseline results from column 3 in Table 3. Column 2 captures the introduction of the white potato alone, allowing for the possibility of the white potato being a staple crop. Column 3 includes both the measures for the introduction of maize and the introduction white potatoes, allowing for the possibility of the white potato being a supplemental crop. Column 4 includes the maize and rice measure with the introduction of maize, and column 5 includes both of alternative crop measures with the introduction of maize measure. Each specification includes state and period fixed effects as well as the controls for European contact and climate. Standard errors are clustered at the state level.

Column 2 tests whether the introduction white potato alone instead of maize is what is driving the baseline results. I find similar effects for the white potato as I did for maize, but the effects are weaker overall. A one percent increase in white potato growing suitability increases urbanization by 0.00315 percent, but this estimate is only marginally significant. There is no apparent effect of increasing the growing suitability of the white potato on population density. It is possible that areas that are more suitable for maize are also more suitable for white potatoes, and given that they are introduced around the same time, these results may just be picking up on the introduction of maize. There is also historical evidence that at this time the white potato was not a staple crop and did not have widespread adoption (**Nunn2011**) like maize, but a supplemental crop (**Mazumdar1999**). Column 3 explores this hypothesis by including the introduction of the white potato along with the introduction of maize. This specification shows that it is the introduction of maize and not the white potato that is responsible for the baseline results. Increasing maize suitability does not have an effect on population density but it does affect urbanization controlling for the introduction of the white potato. A 1 percent increase in maize suitability increases urbanization by 0.00377 percent, though this result is also only significant at the 10% level.

Next I examine whether maize is a supplemental crop for rice and if areas that have better growing conditions for rice and maize experience more economic growth after the introduction of maize. Column 4 includes the maize and rice measure along with the measure for the introduction of maize. When testing this hypothesis, I do not find any effects for the effect of maize on population density, or on urbanization. Areas that have both good growing conditions for maize and for rice also do not experience greater population density or urbanization. States with better suitability for both crops actually see declines in population density. Even though this effect is not significant, combined with the other results, it is suggestive that maize did not function as a supplemental crop.

In column 5, I include each of the different crop measures to control for the effects of these other crops. I again do not find any significant effects on the introduction of maize or the other crops for population density or urbanization. The inclusion of these additional controls do not appear to improve the econometric model above the preferred specification from column 3 of the baseline results. Including the other crops along with maize reduces the adjusted R^2, suggesting that the additional variables do not improve the models' ability to explain the variation in population density or urbanization. The Akaike information criterion tells a similar story. Compared to the other models the Akaike information criterion points to the baseline model as the best specification for both of these outcomes. This suggests that the introduction of maize does increase urbanization.

Another alternative explanation for the increase in urbanization in the spread of the Mughal Empire. The Mughal Empire began in 1530 and continued through 1858 when the British Raj began, and at its peak consisted of most of the Indian sub-continent. The empire was a centralizing state and with each expansion, the empire sought to collect more resources

Table 4: The Effects of Other Crops on Economic Growth

	(1)	(2)	(3)	(4)	(5)
Panel A: Population Density					
ln(Maize)xPost	0.0131		0.0194	0.0306	0.0262
	(0.0161)		(0.0211)	(0.0632)	(0.0658)
ln(Potato)xPost		0.00487	-0.00726		-0.00563
		(0.0120)	(0.0158)		(0.0193)
ln(Maize)xln(Rice)xPost				-0.00457	-0.00216
				(0.0150)	(0.0181)
Adjusted R^2	0.978	0.977	0.977	0.977	0.977
AIC	-482.2	-480.7	-480.5	-480.4	-478.6
Panel B: Urbanization					
ln(Maize)xPost	0.00446***		0.00377*	0.000620	0.000659
	(0.00157)		(0.00218)	(0.00642)	(0.00636)
ln(Potato)xPost		0.00315*	0.000792		0.0000506
		(0.00178)	(0.00239)		(0.00253)
ln(Maize)xln(Rice)xPost				0.00100	0.000983
				(0.00181)	(0.00193)
Adjusted R^2	0.500	0.492	0.497	0.498	0.495
AIC	-1096.2	-1093.5	-1094.4	-1094.7	-1092.7

Table reports the estimates of the effect of maize on population density and urbanization. Panel A reports the results from the regression of the natural log of population density (people/km^2) regressed on the natural log of maize suitability interacted with an indicator for post maize introduction and other controls. Panel B reports the results from the regression of the natural log of urbanization (urban population/total population) regressed on the natural log of maize suitability interacted with an indicator for post maize introduction and other controls. All columns include controls for European contact and climate. The post maize introduction variable and the post potato introduction variable takes the value of 1 for any period after 1615. All regressions include state and period fixed effects. Standard are clustered at the state level and reported in parentheses. * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$

Table 5: The Effect of the Expansion of the Mughal Empire

	(1) log Population Density	(2) log Urbanization
ln(Maize)xPost	0.0161	0.00370**
	(0.0144)	(0.00157)
Mughal	0.135**	-0.00817*
	(0.0528)	(0.00441)
Mughal × ln(Rice)	-0.0340**	0.00225
	(0.0162)	(0.00145)
Observations	198	198
Adjusted R^2	0.979	0.489

Table reports the estimates of the effect of maize on population density and urbanization. Column 1 reports the results from the regression of the natural log of population density (people/km^2) regressed on the natural log of maize suitability interacted with an indicator for post maize introduction and other controls. Column 2 reports the results from the regression of the natural log of urbanization (urban population/total population) regressed on the natural log of maize suitability interacted with an indicator for post maize introduction and other controls. All columns include controls for European contact and climate. The post maize introduction variable and the post potato introduction variable takes the value of 1 for any period after 1615. All regressions include state and period fixed effects. Standard are clustered at the state level and reported in parentheses. * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$

through a land tax (**Richards2003**). This tax brought more lands into cultivation and increased the production of rice throughout the subcontinent (**Richards2003**). It is through the expansion of the empire and the increased cultivation of rice that the empire may directly affect population density and urbanization. To account for this, I map the territories of the Mughal Empire onto modern-day Indian states by period, and include an indicator variable for whether the state was part of the empire during that period. I also interact this indicator variable with the state average suitability for growing rice to account for in increases in rice production that occurred after the expansion of the Empire.

Table 5 presents the results for including the Mughal Empire indicator and its interaction with state average rice suitability. The outcome in column 1 is the natural log of population density and it is the natural log of urbanization in column 2. The results from these specification follow a similar pattern to the preferred baseline estimates for the introduction of maize. The introduction of maize does not appear to affect population density, but it does appear to increase urbanization. Increasing the average suitability of growing conditions for maize by 1 percent, increases urbanization by 0.0037 percent. The estimate is lower than the baseline results, but still of a similar magnitude. This means that when controlling for the effects of the expansion of the Mughal Empire, the introduction of maize accounts for 7.5% of the growth in urbanization.

The results in Table 5 also shows that the expansion of the Mughal Empire did have an impact on both population density and urbanization. For population density, the expansion of the empire had a direct impact as well as an indirect impact through its increased cultivation of rice. After the Mughal Empire expanded into a state, population density grew by 13.5 percent on average. This affect is more pronounced in areas that are not as suitable for growing rice. Increasing the suitability for growing rice in states that were part of the Mughal Empire by 1 percent decreases population density by 0.034 percent on average. One possible explanation for the decreased effect of empire expansion on state with better rice growing conditions is that since the land was more productive in those states, it took less labor to produce the same amount of rice, thereby reducing the population density of those states relative to less productive states.

The expansion of the Mughal Empire also affects the amount of urbanization in a state. Though, the effect of the expansion of the empire is different on urbanization than for population density. After the Mughals expand their empire into a state, urbanization decreases by 8.17 percent on average. Even though the population is increasing after the expansion of the empire, it is not adding more people to urban areas, which is again consistent with the increase in new lands being cultivated in order to pay the land tax extracted by the empire. There is suggestive evidence that in states that were better suited for growing rice urbanization increased, which is consistent with the possible explanation for the negative effect of increased rice suitability in Mughal states for population density, but the result is not statistically significant.

5.3 Spatial Spillovers

After testing alternative explanations, the introduction of maize appears to not have an effect on population density, but it does increase urbanization on average. However, regions do not grow uniformly. Trade patterns and forces of agglomeration can cause some regions to grow while others do not share in the same prosperity. Trade patterns may increase the populations of neighboring regions as more people move to areas of high trade for better market access. This may also affect urbanization. Agglomeration may negatively affect the urbanization of a neighbor as one area becomes a central hub and the outlying areas exist on the periphery to supplement the primary center. Both of these forces may arise because of the expansion of the Mughal Empire and its effects on population and urbanization. To account for these spillovers, I estimate a spatial panel model with spatial lags of the dependent variable.

By including a spatial lag of the dependent variable, I am able to account for these inter-state spillovers. The dependent variable for each state is included as a regressor and is weighted based on its relationship to all other states. For these spatial models, I use a contiguity weighting matrix. This means that for an individual state, the dependent variable of the neighbors for which it shares a border are given a weight of 1 and all other states with which it does not share a border receive a weight of 0. A contiguity weighting matrix make sense in this context because the Indian sub-continent is large and many of the states are also geographically large, so it is more likely that a state's neighbors have a greater influence on its development than a state that is geographically distant.

It is possible that there may be spatial correlation of the idiosyncratic errors as well. Following the procedure in **Beenstock2019**, I perform the Moran test for spatial dependence of the errors and for both outcome. In each case I fail to reject the null hypothesis that the errors are i.i.d. (population density $\chi^2_1 = 0.97$ and urbanization $\chi^2_1 = 0.07$). Based on the results of this test I focus on the spatial lag of the dependent variable in stead of spatial error models or the spatial Durbin model.

Table 6 presents the results from these spatial models. I use two different specifications: one that is analogous to the baseline specification with controls for European contact and climate (column 1) and one that is analogous to the specification with controls with the Mughal Empire (column 2). Panel A and Panel B present the results for population density and urbanization, respectively.

When accounting for spatial spillovers from neighboring states, the introduction of maize does have a positive and statistically significant effect on population density. These effects cannot be interpreted directly, however. If the introduction of maize increases population density in state A, then that increase in state A spills over to further to other states, then that effect will spillover again onto state A, and so on. Instead the average effects from this recursive process must be examined. These effects are presented in Table 8. The total impact of a variable is comprised of its direct impact and its indirect impact. The direct impact is the effect of of a change within the state without accounting for spatial spillovers. The indirect impact is the spillover effect.

Table 6: Spatial Spillovers and the Effect of Maize on Economic Growth

	(1)	(2)
Panel A: Population Density		
ln(Maize)xPost	0.0266***	0.0261**
	(0.00987)	(0.0112)
Mughal		0.115**
		(0.0482)
Mughal × ln(Rice)		-0.0260
		(0.0171)
Wc		
log Population Density	-0.0971***	-0.0932***
	(0.0301)	(0.0296)
Observations	198	198
Wald Test of Spatial Terms	10.43	9.941
Panel B: Urbanization		
ln(Maize)xPost	0.00424***	0.00397**
	(0.00146)	(0.00178)
Mughal		-0.00898
		(0.00791)
Mughal × ln(Rice)		0.00240
		(0.00278)
Wc		
log Urbanization	-0.130	-0.151
	(0.129)	(0.130)
Observations	198	198
Wald Test of Spatial Terms	1.012	1.349

Table 7: Table reports the estimates of the effect of maize on population density and urbanization. Panel A reports the results from the regression of the natural log of population density (people/km^2) regressed on the natural log of maize suitability interacted with an indicator for post maize introduction and other controls. Panel B reports the results from the regression of the natural log of urbanization (urban population/total population) regressed on the natural log of maize suitability interacted with an indicator for post maize introduction and other controls. Wc log population density and log urbanization are spatial lag terms weighted by contiguity. the All columns include controls for European contact and climate. The post maize introduction variable and the post potato introduction variable takes the value of 1 for any period after 1615. All regressions include state and period fixed effects. Standard are clustered at the state level and reported in parentheses. * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$

Table 8: Estimated Impacts on Population Density and Urbanization

	(1)			(2)		
Panel A: Population Density						
	Direct Impact	Indirect Impact	Total Impact	Direct Impact	Indirect Impact	Total Impact
ln(Maize)×Post	0.0266***	-0.0018*	0.0248***	0.0262**	-0.0017*	0.0244***
	(0.0099)	(0.0010)	(0.0090)	(0.0112)	(0.0010)	(0.0103)
Mughal				0.0422***	-0.0025*	0.0397***
				(0.0171)	(0.0014)	(0.0160)
ln(Rice)				-0.0137	0.0010	-0.0127
				(0.0090)	(0.0006)	(0.0084)
Panel B: Urbanization						
ln(Maize)×Post	0.0043***	-0.0004	0.0039***	0.0040**	-0.0004	0.0036**
	(0.0015)	(0.0004)	(0.0013)	(0.0018)	(0.0004)	(0.0016)
Mughal				-0.0023	0.0002	-0.0021
				(0.0028)	(0.0003)	(0.0025)
ln(Rice)				0.0013	-0.0001	0.0011
				(0.0015)	(0.0002)	(0.0013)

These results indicate that a 1 percent increase in the suitability conditions for growing maize has a direct impact on a state's population density, increasing it by 0.0266 percent. The spillover effect of increasing maize by 1 percent is to reduce population density by 0.0018 percent. Together, the total impact on population density is a 0.0248 percent increase. When taking the effects of Mughal expansion and its impact on rice cultivation, the results for the impact of the introduction of maize remain stable. A one percent increase in the growing conditions for maize increase population density by 0.0244 percent (0.0262 direct effect and -0.0017 indirect effect). The negative indirect effects suggest that populous state attracts more population growth from its neighboring states, concentrating density into a select number of states.

The expansion of the Mughal Empire also impacts the population density within a state. The average total impact of the Empire expanding into a state increases population density by 3.97 percent. There are also negative spillovers associated with the expansion of the Mughal Empire. The indirect effect of expansion decreases population density by 0.25 percent.

The results in Panel A suggest that when accounting for population spillovers, the introduction of maize does have a net positive effect on population density. The estimated effect is small, and it is unclear whether this result is economically significant. To better understand how maize impacts populations density, I determine the introduction of maize's contribution to the overall growth in population density. The introduction of maize increased the population density of the average state between 7.8% and 7.7% (total impact of the introduction of maize multiplied by the average maize suitability of 3.15). According to the data, the average state had a population density of 42.5 people per square kilometer in 1600 and 82 people per square kilometer in 1800. This suggests that population density grew by about 93%. Thus maize contributed to about 8.2% of the increase in population density during this period, which is a similar effect as the expansion of the Mughal empire.

Panel B of Table 8 shows that when controlling for spatial spillovers, there is also a positive and significant effect of the introduction of maize on urbanization. Increasing the suitability for growing maize by 1 percent increases the urbanization in a state between 0.0036 percent and 0.0043 percent. The individual indirect effects are not statistically significant, so the range of potential impacts spans the range for both the total and direct impacts. These results are consistent with other specifications for urbanization. Based on these estimates, the introduction of maize contributes between 7% and 8% of the growth in urbanization from 1600 to 1800, which is the same contribution as the baseline estimates.

The effect of the expansion of the Mughal Empire on urbanization is of similar magnitude as in Table 5, however this effect is no longer statistically significant when controlling for spatial dependencies between states. There is also no effect of increased rice cultivation because of the Mughal empire. In contrast to the spatial spillovers from population density, the average spatial spillovers are not statistically different from 0. However, I fail to reject the null hypothesis that all spatial terms are equal to 0 for both specifications ($\chi^2_1 = 1.012$

and $\chi_1^2 = 1.349$). This suggest that there are some spatial dependencies between states that should be accounted for despite their average effect being statistically insignificant.

The results from Panel A combined with the results in Panel B suggest that the introduction of maize did impact economic growth in India before 1800. Its introduction increased both population density as well as urbanization, two indicators, which when taken together, suggest that economic growth did occur. Maize was a significant enough agricultural productivity shock that India was able to escape its Malthusian paradigm.

6 Conclusion

This paper analyzed the impacts of the introduction of a New World crop in the economy of Pre-colonial India. For the introduction of a New World crop to impact the economy is must provide a sufficient technological shock by being richer in necessary nutrients and more productive than existing crops. This paper finds evidence that maize fulfills these criteria. Using variation in the ability of states to successfully grow maize, I find that the introduction of maize did significantly increase modern economic growth during this time period when accounting for spatial spillovers. Increasing the suitability for growing maize by 1% increases population density by 0.0244% and urbanization by 0.0036%, which means that for the sample period, the introduction of maize contributed 9% of the total population growth and 8% of the total growth in urbanization.

Alternative explanations for the growth in population density and urbanization were also tested. One explanation was the possibility that other crops caused were the determinant of this growth instead of maize. When these alternative crops were included, the impact from the introduction maize was no longer statistically significant, but other measure indicate that these alternative specifications do not perform as well as the simple difference-in-differences, baseline results. Another explanation, was the effect of the expansion of the Mughal Empire impacted economic growth. I do find some evidence for this hypothesis, but even when controlling for these factors maize continues to be a determinant of the growth in urbanization and population density.

The spatial aspect of economic growth is also an important consideration. The growth from one state can impact another, which then recursively impacts the first. I do find that this dynamic occurs for the introduction of maize, and the net result of the direct and indirect impacts increases economic growth. This suggests that the introduction of maize is a sufficient agricultural productivity shock to spur economic growth, and that the introduction of maize did allow for India to escape its Malthusian trap during this period of history.