Seed Capital: The Impact of Agricultural Output on Local Economic Activity in India *

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Abstract

To what extent do firms rely on rural output for demand and capital? We provide new evidence on this classic development question by examining the impact of agricultural output on local economic activity. Rainfall provides exogenous and significant variation in rural earnings. We find that such fluctuations have a lasting impact on urban firms, with effects concentrated in the manufacturing sector. Using variation in both location and industry characteristics of firms, we demonstrate that the evidence best supports a capital channel by which rural surplus provides capital to small, credit-constrained manufacturing enterprises. We argue that given these constraints, a complete understanding of the impact of agriculture must assess changes in both rural and nearby urban firms.

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1 Introduction

What consequences do sector-specific shocks have on local economic activity? In a highly integrated world, the answer should be little to none. Of course, the world is still characterized by limited mobility in many goods, both intermediate and final. These frictions apply both to productive inputs, such as labor (Behrman, 1999), capital (Banerjee, 2003; La Porta et al., 2002) and information (Jensen, 2007), as well as in output markets (Limao and Venables, 2001; Donaldson, 2010). A large "big push" literature shows how the decisions of firms can depend on the choices of other local firms (see, for example, Murphy et al. (1989)); these dependencies are increasing in the immobility of goods, meaning that the location decisions of firms will be determined more by the availability of inputs and local demand in low-income than in richer nations (Venables, 2005).

In this paper, we test for the impact of shocks on firms in unrelated sectors in India. We utilize exogenous variation in agricultural output due to weather to estimate the dependence of firms on the local rural economy. In constrast to recent work on the United States (Hornbeck and Keskin, 2012), we find that strong evidence that agricultural shocks have large and persistent consequences for local firms, particularly in nearby urban areas.

We consider India to be an optimal setting for this research. By taking advantage of within-country variation in agricultural output, we are able to eliminate immobilities of goods and labor that exist at national borders. Furthermore, India is a large developing country with many of the constraints faced by other low-income countries. Finally, India is a large country with considerable heterogeneity in local economic conditions, such as infrastruture and industrial composition, that allow us to determine the characteristics of industries and locations that make shocks more or less important for local economic activity.

This research is closely related to Mian and Sufi (2012). They find that increases in local unemployment in the United States following the financial crisis in 2008 were closely tied to shocks to household balance sheets. They argue that a decrease in local demand explains much of the observed increase in unemployment, citing as evidence their finding that only local nontradable employment was correlated with the intensity of changes to household balance sheets.

Our findings support a somewhat different story. We find that increases in agricultural income cause significant employment growth in urban manufacturing firms. We argue that this is evidence for immobilities in either inputs or outputs. Local demand does not fit our findings well: areas wtih low transportation costs exhibit weakly greater growth in manufacturing compared to areas where transportation costs are greater. If manufacturing employment were growing in response to increases in local demand, we would expect to see the greatest response to agricultural income in locations with high transportation costrs. Instead, a capital channel best explains our results. An positive shock to agriculture causes an increase in employment in firms reporting a reliance on local, informal capital. This is consistent with recent evidence suggesting that local sources of savings matter even for financial access in the United States (Gilje, 2012), although credit constraints are widely considered to be more binding in developing countries. Reasons for this include contracting (Banerjee, 2003) and political interference (La Porta et al., 2002).[1]

Our findings support an intermediate level of localization of capital markets. Specifically, we reject both autarky and perfect mobility of goods. Changes to manufacturing employment in local urban areas make clear that capital flows between them and rural areas where agricultural shocks occur.

Finally, we contribute to a large literature on the role of agriculture in development. We provide evidence that weather shocks promote structural transformation: the number of workers in agriculture decreases following positive rainfall shocks. However, we find no evi-

[1] Burgess and Pande (2005) find significant decreases in rural poverty as the result of a major banking expansion in India.

dence of permanent migration. Theoretically, the impact of shifts in agricultural output are unclear: on the one hand, increases may stimulate demand, provide capital for investment and supply inputs to the non-agricultural economy. On the other hand, increased agricultural productivity increases the returns to labor and capital in agriculture, potentially crowding out other activities. Empirical evidence reflects this ambiguity. Some researchers have found that agricultural productivity gains facilitate economic growth and development (Gollin et al., 2002; Nunn and Qian, 2011), while others have found that they crowd out non-agricultural activities (Foster and Rosenzweig, 2004).[2] We should be clear that our shocks are best understood as windfalls, rather than the permanent shifts in agricultural productivity typically discussed in the literature. More closely related to this paper, Dercon (2004) provides evidence that temporary rainfall shocks can produce persistent differences in consumption in Ethiopian villages.

This paper proceeds as follows: Section 2 develops a theoretical framework to organize our examination of the relationship between agricultural productivity shocks and employment in the nonfarm economy. Section 3 explains the various sources of data used and how the key variables are constructed. Section 4 develops the empirical strategy that is used to identify the impact of agricultural income on nonfarm employment, also providing summary statistics of the main variables. Section 5 presents the primary results. Section 6 concludes.

2 Theoretical framework

In this section we develop a theoretical framework for understanding how temporary shocks to agricultural productivity will affect firms in the non-farm economy. The purpose is to demonstrate how, depending on mobility of inputs and output, agricultural productivity

[2]For a comprehensive survey of the theory and evidence, see Douglas Gollin's chapter in the Handbook of Agricultural Economics (Gollin, 2010). For a more policy-focused survey, see the 2008 World Development Report: Agriculture for Development (World Bank, 2008).

shocks can either crowd-out or crowd-in employment and production in nonfarm sectors.

2.1 Assumptions

Consider a small open economy (say, a village) with two productive sectors: agriculture and other. Each sector is modeled as a single, profit-maximizing firm. Agricultural production utilizes only labor:

$$Y_A = \theta ln(L_A) - wL_A,$$

where $\theta > 0$ is stochastic and represents temporary weather-related productivity shocks.

Production of the other sector, which we call tradable, is CRS Cobb-Douglas in capital and labor:

$$Y_T = AK_T^{\alpha} L_T^{1-\alpha},$$

where capital share $\alpha \in (0, 1)$ with permanent TFP parameter A.

Agents are modeled as a single unitary household with Cobb-Douglas preferences over consumption of agricultural and tradable goods:

$$U(C_A, C_T) = C_T^{\gamma} C_A^{1-\gamma},$$

ensuring that that expenditure on consumption of tradables $p_T C_T$ is a constant share γ of total consumption $\overline{C}$. The price of agricultural goods is the numeraire, yielding:

$$C_A = (1 - \gamma)\overline{C}.$$

For simplicity, intertemporal allocation of consumption is decided by a fixed savings rate s, meaning that current consumption is a fixed proportion of current income:

$$\overline{C_t} = (1 - s)I_t.$$

Income not saved is added to the local capital stock $\overline{K}$, producing the following equation of motion for capital:

$$\overline{K_t} = sI_{t-1} + \overline{K}_{t-1}.$$

Labor is immobile across space, but not across sectors. The total labor supply available in the village is normalized to 1; therefore $L_A + L_T = 1$. Given labor mobility across sectors, the wage w must be equal in agriculture and the tradable sector.

We consider two market frictions that determine how shocks to the agricultural sector will affect the nonfarm economy. The first, transport costs, are modeled as iceberg costs $\tau \geq 1$: for one unit exported to the outside market, $\frac{1}{\tau}$ arrives at its destination. For simplicity, these transport costs apply only to the non-agricultural good, although applying them to agriculture does not fundamentally change the analysis. The price of the traded good in the outside market is p_T. Outside firms are indifferent between selling locally or to the outside market, thus fixing the local price of the tradable good at τp_T. Likewise, local producers selling to the outside market face an effective price of $\frac{p_T}{\tau}$.

Transport costs for capital, long a concern for development economists (Besley, 1995), are the other friction. These create a wedge between the local and outside opportunity cost of capital. As with τ above, $\phi \geq 1$ represents the cost of moving one unit of capital into or out of the local market. The interest rate r in the outside market applies to both savings and borrowing. Thus the cost of capital faced by firms borrowing locally is $\frac{r}{\phi}$, while the cost of capital borrowed from the outside market is ϕr.

Frictionless markets in capital and tradable goods is achieved by setting $\tau = \phi = 1$. For τ or ϕ greater than one, there is a wedge between the inside and outside prices of goods and capital, changing the impact that agricultural productivity shocks have on the other sector.

2.2 Production Maximization Problem

Solution of the model hinges on the source of marginal demand and marginal capital for the tradable industry. Due to the transport costs of tradable goods τ, the firm will first sell tradable goods to local market at τp_T. Only once local demand is fully satisfied will the firm sell to the outside market at effective price $\frac{p_T}{\tau}$. Due to capital transport costs ϕ, the firm will first rent local capital at $\frac{r}{\phi}$ before renting outside capital at interest rate ϕr. Thus there are four scenarios that determine equilibrium production and the relationship between production in the two sectors. In the first, marginal production is sold to the outside market at the lower effective price $\frac{p_T}{\tau}$ and marginal capital is borrowed at the higher rental rate ϕr. In the second, marginal demand for tradable goods is still from the outside market, but marginal capital is rented locally. In the third scenario, the opposite is true: marginal demand is local while marginal capital comes from the outside market. Finally, the fourth scenario is effective autarky: no tradable goods are sold to the outside market, nor is capital borrowed from the outside.

Regardless of the which scenario the economy is in, profit maximization in the agricultural sector yields $L_A^* = \frac{\theta}{w^*}$; combined with the time budget constraint, we get $L_T = 1 - L_A = 1 - \frac{\theta}{w^*}$. Thus it is easy to see the first effect that transitory shocks have on nonfarm employment: in the absence of other forces, a high realization of θ will raise demand for labor in the agricultural sector, crowding out employment and production in the tradable sector.

2.2.1 Outside demand, outside capital

In the benchmark case, the tradable firm sells its production both locally and to the outside market, as well as using capital sourced locally and from the outside. As prices for its output are higher locally, it fulfills all local demand before selling remaining output to the external market. As the rental rate of capital is lower internally, the firm rents the full local capital stock $\overline{K}$ before renting additional capital from the outside market. The relevant prices that determine the scale of production are the price faced at the margin, $\frac{p_T}{\tau}$, and the rental rate of capital faced at the margin, ϕr.

Given CRS production in the tradable sector, zero marginal profits fix the only equilibrium wage for which there will be positive sales to the outside market:

$$w^* = (1-\alpha)(\frac{p_T A}{\tau})^{\frac{1}{1-\alpha}}(\frac{\alpha}{r\phi})^{\frac{\alpha}{1-\alpha}}.$$

The time budget constraints produces a solution for employment in the tradable sector:

$$L_T = 1 - L_A = 1 - \frac{\theta}{w^*}. \tag{1}$$

It should be noted that transport costs in both the goods and capital markets depress the wage, leading to higher employment in agriculture and lower in the tradable sector. How does employment in the tradable sector respond to agricultural productivity shocks? Differentiating equation 1 by θ yields:

$$\frac{\partial L_T}{\partial \theta} = \frac{-1}{1-\alpha}(\frac{\tau}{p_T A})^{\frac{1}{1-\alpha}}(\frac{r\phi}{\alpha})^{\frac{\alpha}{1-\alpha}} < 0.$$

Thus in our benchmark case, a high realization of θ unequivocally crowds out employment in the tradable sector. Both goods and capital transport costs amplify the crowd-out. The case of frictionless markets, with $\tau = \phi = 1$, is a particular example of this scenario, which leads to the following proposition.

Proposition 1. Employment in the tradable sector is strictly decreasing in θ under either of the following conditions:

- Frictionless markets, defined as iceberg costs of goods (τ) and of capital (ϕ) both equal to 1.

- The firm sells positive output to the outside market and borrows positive capital from outside lenders.

2.2.2 Outside demand, local capital

In this scenario, the firm still sells a positive amount of output to the outside market after meeting all local demand; however, it now finds itself credit constrained. At the local capital rental price, it demands more capital than the local capital stock ($K_T^*(\frac{r}{\phi}) > \overline{K}$), but it is not profitable for the firm to borrow capital from the outside market ($K_T^*(\phi r) = 0$). [3] The firm thus chooses L_T subject to $K_T = \overline{K}$. This maximization yields:

$$L_T^* = \overline{K}\big(\frac{(1-\alpha)Ap_T}{w^*\tau}\big)^{\frac{1}{\alpha}},$$

where w^* satisfies the following equality:

$$1 = \frac{\theta}{w^*} + \overline{K}\big(\frac{(1-\alpha)Ap_T}{w^*\tau}\big)^{\frac{1}{\alpha}}.$$

It is easy to see that even with capital constraints, tradable employment and production is crowded out by high realizations of agricultural productivity, which pushes up the wage. Because the tradable sector is dependent on local capital, however, its scale of production is increasing in $\overline{K}$, which is itself increasing in past realizations of θ. We thus have under this scenario that current agricultural productivity crowds out tradable production, while past agricultural productivity crowds in tradable production.[4]

[3] In fact, another scenario is possible where the firm uses only local capital but does not find itself credit constrained. This is when the level of capital demanded at the local rental rate of $\frac{r}{\phi}$ is less than the local capital stock $\overline{K}$. This scenario becomes the same as in Section 2.2.1, but where the rental rate ϕr is replaced with $\frac{r}{\phi}$.

[4] In fact, the capital stock has countervailing effects on tradable employment. Higher local capital stock increases returns to labor in the tradable sector, increasing employment. However, it also increases the wage,

2.2.3 Local demand, outside capital

In this scenario, the tradable sector meets local demand but finds it unprofitable to export to the outside market. It does, however, borrow capital from the outside market. In this equilibrium, it minimizes costs subject to meeting local demand C_T. This leads to the following employment in the tradable sector:

$$L_T^* = \overline{K}\Big(\frac{(1-\alpha)Ap_T}{w^*\tau}\Big)^{\frac{1}{\alpha}},$$

where w^* solves the following equality, coming from the fixed supply of labor:

$$1 = \frac{\theta}{w^*} + \overline{K}\Big(\frac{(1-\alpha)Ap_T}{w\tau}\Big)^{\frac{1}{\alpha}}.$$

Current agricultural productivity has countervailing effects on employment in the tradable sector. On the one hand, it lowers tradable employment by increasing returns to labor in agriculture and the equilibrium wage; on the other hand, it increases income and thus local demand for tradable goods. The total effect is ambiguous. Past agricultural productivity has an unequivocal positive effect on tradable production by increasing the capital stock and thus current income. This scenario is characterized by a demand constraint on tradable production, leading to an increase in tradable production and labor.

2.2.4 Local demand, local capital

In the final scenario, the tradable sector neither sells to the outside market nor does it borrow capital from the outside market. There are actually three possibilities here. In the first, the firm demands less capital than is available at the local rental price ϕr and produces less than is demanded at the local price $\frac{p_T}{\tau}$. This case is equivalent to Section 2.2.1

lowering tradable employment. By differentiating the household time budget constraint with respect to the capital stock, it is easy to show that the former effect strictly dominates.

but where the relevant prices are ϕr and $\frac{p_T}{\tau}$. We know from Section 2.2.1 that in this case, tradable employment and production are decreasing in agricultural productivity. In the second possibility, the firm is not constrained by local demand but is constrained by local capital $\overline{K}$ and finds it unprofitable to sell to the outside market; this is analogous to Section 2.2.2 but with marginal revenue τp_T. In the third possibility, the firm is constrained by local demand but not by the local supply of capital; this is analogous to Section 2.2.3 but with marginal price of capital $\frac{r}{\phi}$.

Finally, the firm may be constrained by both demand and capital, without finding it worthwhile to produce for the outside market or borrow additional capital. In this case, the firm simply employs enough labor to meet local production:

$$L_T^* = (\frac{C_T}{A\overline{K}^{\alpha}})^{\frac{1}{1-\alpha}}.$$

The wage is then set to satisfy the time budget constraint. Employment in the tradable sector is increasing in agricultural productivity via demand for tradable goods. Past agricultural productivity, however, produces competing effects through its impact on the capital stock. A greater capital stock increases capital earnings and thus demand for tradable goods. However, it also crowds out demand for labor, as labor in the tradable sector will only be sufficient to meet local demand in this scenario.

2.3 Discussion

In the absence of market frictions that limit the mobility of inputs to or outputs from the non-agricultural sector, positive agricultural shocks crowd-out production and employment by increasing competition for common inputs, modeled above as only labor. Crowd-out may occur, despite the presence of frictions in input and output markets, if the marginal source of inputs and demand comes from outside the local area and is thus independent of local agricultural productivity shocks.

However, for any firms that on the margin depend on local inputs or demand, such shocks can crowd-in rather than crowd-out non-farm economic activity. In the model presented above, costs associated with the movement of inputs and outputs play analogous roles. This is due to the dual effects of agricultural productivity shocks: they affect demand via earnings and capital supply via savings.

In order to test between these channels, it is necessary to identify the determinants of these frictions. Firms will be more likely to depend on local marginal demand in the presence of high transportation costs. These costs may result from characteristics of the industry, such as a high weight-to-value ratio, or of the location, such as low quality road infrastructure. Costs associated with outside borrowing, on the other hand, will depend on the availability of financial services. These location and establishment characteristics will provide the basis for the empirical tests discussed in the following sections.

For the interpretation of the results presented in this paper, it is necessary to consider how transitory output shocks differ from the long-term agricultural productivity growth that is often considered in the literature. There are two primary differences. The first is that in terms of permanent income, a one or even five year period of good rain is much smaller than a permanent increase in agricultural productivity of the same annual magnitude. Second, weather-induced output shocks should not change expectations of long-run income. How do these differences matter in the framework discussed above? A permanent shift in agricultural productivity would lead to a permanent shift in local demand, leading to a level expansion in the size of the nontradable sector. A temporary shock, on the other hand, will in the absence of market frictions lead to a much smaller increase in the long-run size of the nontradable sector, as demand in the long-run will depend only on the portion of the shock that was saved and continues to provide income to households many years after the shock. In a standard dynamic savings model, current consumption should not increase much as expectations over lifetime earnings will have changed only slightly. Thus, short-term shocks should result in larger changes to savings and smaller changes to consumption than equivalent changes in long-term agricultural productivity.

3 Data and construction of variables

3.1 Data

In order to examine the relationship between agricultural production and business activity, it was necessary to link datasets containing information on firms, location characteristics, agricultural production, land use and irrigation status and weather.

The Indian Economic Census is a comprehensive enumeration of all firms not engaged in crop production, both formal and informal. We use firm-level data from the 3rd, 4th and 5th rounds, undertaken respectively in 1990, 1998 and 2005.These data are publicly available from the Ministry of Statistics and Programme Implementation (MoSPI), but are not organized as a panel. With the assistance of location keys from MoSPI, we constructed panels at the village, town, district and subdistrict levels, then linking them to population census identifiers. The Economic Census contains a small number of characteristics about each firm, including the number of employees and some of their characteristics, the firm's source of power, details about the firm's registration, and the industrial code of the primary product.[5]

The Indian Population Census provides village and town demographic data in 1991 and 2001, as well as local public goods (roads, electricity, schools and hospitals), distances from villages to major towns, and land area. We obtained geographic coordinates for population census locations from ML Infomap and matched them to weather data (described below) and

[5]It is worth noting that this includes privately owned establishments, state-owned establishments and government establishments like schools and health centers.

to bounding polygons of administrative units. All population and economic census data was then aggregated to 1991 Population Census subdistrict level for rural areas and the district level for both urban and rural areas. For all results coming from the Economic Census, we measure employment growth as change in employment from 1990-98 and 1998-2005.

Agricultural data comes from a variety of sources. District-level data on area, production and prices by crop, 1990-2005, comes from the Center for the Monitoring of the Indian Economy and from the Indian Ministry of Agriculture. Subdistrict-level cropping patterns and irrigation data come from the Indian Agricultural Census of 1995, 2000, and 2005.[6] The Population Census also provides area under cultivation, by irrigation status, in 1991 and 2001.

Weather data for 1971-2005 comes from the Indian Meteorological Department's National Climate Centre (Rajeevan and Bhate, 2008; Srivastava et al., 2009). This dataset uses daily recordings from 6076 (rainfall) and 395 (temperature) weather stations to produce a 0.5 degree x 0.5 grid. We then interpolate weather values to match the geographic units used in our analysis. For subdistricts and districts, we obtain weather values using an average of village values weighted by agricultural land.

Industry measures come from a variety of sources, summarized by 2. Following Moretti (2010), we classify as tradable all industrial sectors that fall under the manufacturing header (Section D) of the 2004 National Industrial Classification of India. We use a cross section of the Indian Annual Survey of Industries (ASI) from 1991-1992 to generate two industry-level measures, both scaled to be between 0 and 1. First, we calculate capital intensity as the ratio of gross fixed capital to labor costs. Second, we calculate reliance on external finance as the ratio of open loans to gross fixed capital. This second measure is in the spirit of Rajan and Zingales (1998), whose measure is highly correlated with our own but limited to just 19 industries that we are able to match with the Indian National Industrial Classification (NIC).

[6] Data was scraped in the spring of 2012 from dacnet.nic.in.

For tradability, we match commodity-level data from the United States Census Commodity Flow Survey (CFS) of 2007 to NIC codes, providing a measure for each industry of the average shipping distance of its major commodity, a direct measure of the transportability of goods given the quality of infrastructure found in the United States. Our location-level measure of transportation costs estimates the cost of shipping goods on the Indian highway network. Using both the data and methodology of Lall et al. (2004), we estimate transportation costs from the district centroid to the nearest city with a population of at least 500,000, according to the 2001 Population Census. We consider this a much stronger measure of the relevant transportation costs in a given area than widely used alternatives, particularly the quality of rural roads, since the transport costs that will determine whether demand for tradable goods is met by local or outside firms is the cost of moving goods in and out of the district, not from the local town to the agricultural areas.[7]

The Input-Output Tables produced by MoSPI provide industry measures of input intensity: the share of an industry's non-labor input costs that come from a particular sector of the economy. For example, we construct a measure of agricultural input share, defined as the share of input costs derived from non-timber agricultural inputs. We use the input flow matrix from the 2006-7 update to the 2004-5 Input-Output Tables.

3.2 Construction of variables

Table 1 summarizes the construction of the main variables used in this paper. We construct panels (district and subdistrict) with two periods as defined by the three economic censuses. Period 0 corresponds to 1990 - 1998, while period 1 corresponds to 1998 - 2005. For growth regressions, baseline employment is given by 1990 employment in period 0 and 1998 employment in period 2. Agricultural income is summed over the five years preceding the end of

[7] We thank Henry Jewell and Hyoung Gun Wang, of the World Bank Urban Unit, for generously generating and sharing these data.

the period: 1993-1997 for period 0 and 2000-2004 for period 1.

Following Cole et al. (2012) and consistent with various studies on Indian agriculture (Fishman, 2011; Guiteras, 2009), the primary climactic variable of interest is rainfall during the summer monsoon, defined as total precipitation over the months of June, July, August and September. This period roughly corresponds to the kharif (summer) growing season, although rabi (winter) crops also depend heavily on summer rain (citation). We demean and normalize rainfall values to produce a measure of rainfall that is exogenous to local characteristics. Although agricultural productivity is usually increasing in rainfall, there is the possiblity for too much rain. Like other recent papers (Cole et al., 2012; Hidalgo et al., 2010), we account for this non-montonic relationship between rainfall and agricultural output by defining our rain variable as the absolute value of the difference (in standard deviations) between observed rain and optimal rain for agricultural income, which our calculations suggest is 1.25 standard deviations above mean. As with agricultural income, we sum annual rainfall over the five year period preceding the Economic Census.

Working over a 15 year time period poses challenges towards the creation of a panel, as administrative units can change both name and area. In order to form a panel of districts, it was necessary to account for district splits and other redistributions of land between districts. We use Kumar and Somanathan (2009), as well as data provided by the Ministry of Statistics and Programme Implementation, to construct a panel of consistent districts over time. This involved agglomerating some districts into larger "super districts" when territorial transfers made districts inconsistent over time. From a total of 593 districts at the time of the 2001 Population Census, we construct a panel of 414 consistent districts and "super districts". Of these, we are able to match 388 across all datasets. Dropping small states and union territories reduces this number to 353. Finally, we restrict our sample to those districts in which agriculture is a major industry, keeping only districts that have more than 50% of the population living in rural areas. Missing data and trimming outliers results in 526 district-period observations in the two period panel.

4 Empirical strategy and summary statistics

4.1 Empirical strategy

This section describes the empirical strategy used to estimate the linkages between agricultural output and nonfarm economic activity. As discussed above, weather provides exogenous variation in agricultural output that will be used to estimate the causal impact of agricultural income on nonfarm economic activity.

Let $i = 1, ..., N$ index districts and $\tau = 1, ..., T_0(1990), ..., T_1(1998), ..., T(2005)$ index years. Time periods are indexed using t, which consist of the years between observations of variables; for example, $t = 1, 2$ correspond to the Economic Census periods 1990-1998 and 1998-2005, respectively. The outcome variable of interest is represented by $Y_{i,\tau}$, which in our case is log employment growth. The endogenous variable, agricultural income, is represented by $X_{i,\tau}$. $\tilde{X}_{i,\tau}$ is the $k \times 1$ vector of other explanatory variables and $Z_{i,\tau}$ is the $p \times 1$ vector of excluded instruments. For simplicity, we sometimes use the $(p + k) \times 1$ vector $W_{i,\tau} = (Z'_{i,\tau}, \tilde{X}'_{i,\tau})'$.

The structural equations for our model are:

$$Y_{i,\tau} = \beta X_{i,\tau} + \delta' \tilde{X}_{i,\tau} + \epsilon_{i,\tau} \tag{2}$$

and

$$X_{i,\tau} = \gamma' Z_{i,\tau} + \lambda' \tilde{X}_{i,\tau} + \nu_{i,\tau}, \tag{3}$$

which produce the reduced form equation

$$Y_{i,\tau} = \beta(\gamma' Z_{i,\tau}) + (\delta + \beta\lambda)' \tilde{X}_{i,\tau} + u_{i,\tau} \tag{4}$$

where $u_{i,\tau} = \epsilon_{i,\tau} + \beta\nu_{i,\tau}$.

To go from the model above to the data that we will use, it is necessary to sum up from years (τ) to periods (t) that correspond to the Economic Census; for example, $Y_{i,t=1} = \sum_{\tau=T_0}^{T_1} Y_{i,\tau}$ and $Y_{i,t=2} = \sum_{\tau=T_1}^{T} Y_{i,\tau}$.

5 Results

5.1 Agricultural income

As the identification strategy of this paper relies on the impact of weather on agricultural income, it is first worthwhile to investigate this relationship. Table 3 estimates the impact of rainfall on total crop income at the district level. Column 1 gives the impact of rain on annual district agricultural income, measured in standard deviations from the mean. Column 2 shows that this relationship is not monotonic. Column 3 uses the preferred specification for the rest of the paper, following (Cole et al., 2012), which is rain measured in standard deviations from the district optimum, which we estimate as 1.25 SD above mean. We estimate that an additional standard deviation of rain towards the optimum results in approximately 637 million rupees, or approximately $14.5 million.

5.2 Reduced form

Table 4 uses the same functional form to estimate the reduced form relationship between rain and nonfarm employment growth in rural areas, now controlling for baseline employment as well. There is no significant relationship between rural employment growth and rainfall. Column 1 regresses log employment growth on the sum of rainfall in the five years preceding the economic census. Table ?? repeats the exercise, dividing employment into nontradables and tradables, with tradable industries defined as all those in Section D (Manufacturing) of the Indian National Industrial Classification. Again, we see no significant relationship between rainfall and employment growth. In contrast, Table 6 reveals that urban employment in strongly increasing in rainfall. There does not appear to be an immediate effect; instead, employment growth appears to be increasing as the time between the agricultural income shock and the period of observation occurs. Table 7 divides this growth into nontradable and tradable industries; here we find significantly higher growth in manufacturing industries.

5.3 Channels

The results presented in Section 5.2 make clear that employment in urban manufacturing is strongly increasing in rainfall; one standard deviation increase in rainfall in one of the years preceding the economic census produces approximately 3.4 log points of additional employment growth. As discussed in Section 2, tradable production would only respond to local income in the presence of some frictions in local input or output markets; we therefore take this result to demonstrate the presence of such frictions. These could take a number of forms. In the presence of immobile labor, we would expect to see crowd-out of tradable production, as increased returns to labor in agriculture increase wages that tradable goods producers must pay. This is the opposite of what we find. Instead, this result is more consistent with distance-related costs in either capital or output.

The most plausible story not explored in the model presented in Section 2 is that growth is driven by industries that rely on large quantities of agricultural inputs. It is natural to imagine that brewers and millers will thrive during agricultural booms, simply because of cheaper or more abundant inputs. We examine this by constructing a measure of agricultural input intensity: the share of non-labor input costs derived from agricultural goods, as described in Table 2. We construct a dummy variable for any industry that spends more than 20% of its non-labor input costs on agricultural products. Table 8 shows that in no specification do industries that are intensive in agricultural inputs respond significantly more to rainfall shocks than other industries.[8]

Another potential explanation is that industries themselves may depend directly on water, in which case the identifying assumptions discuss in Section 4 are violated. We consider this unlikely. Only one industry in the input-output tables spends more than 1% of its non-labor input costs on water: water-based transport. Even manufactures of non-alcoholic beverages spend just over 1/10 of 1% of its non-labor inputs costs on water.

If the local availability of investment capital is an increasing function of local savings, then tradable firms meeting external demand would expand in response to a positive shock to agricultural income. Table 10 provides some suggestive evidence for the existence of such a localization of capital markets, examining the share of firms reporting using local finance, as opposed to formal finance. We show that rainfall shocks increase the share of firms reporting use of local finance.

What about demand? There is certainly strong reason to believe that increased demand due to higher incomes from agricultural windfalls leads to employment growth: most of the employment response of the nonfarm economy is in the nontradable sector. Table 9 explores this channel further by categorizing districts as above or below median in road infrastructure, an important determinant of transport costs and thus tradability. We find no evidence for an increase in urban manufacturing employment in those districts that have higher transportation costs; the point estimate on the difference is actually negative, the opposite of what we would expect under scenario where urban manufacturing firms meet local demand.

[8]We do find smaller coefficients on *Rain* than in the main reduced form specification found in Table ??, but this is unsurprising given that we are not able to match all industries in the Economic Census to the industries in the input-output tables.

6 Conclusion and next steps

How do frictions in markets in developing countries affect the spatial distribution of economic activity? Does agricultural income continue to play an important role in determining the economic opportunities of urban firms, or do global capital and goods markets make local income irrelevant. We provide new evidence on this classic question in development economics. We find that shocks to rural agricultural income increase growth in urban areas, with growth concentrated in the manufacturing sector. In testing between demand and capital channels that could explain such manufacturing growth, our evidence suggests that agricultural surplus increases growth in manufacturing firms by providing capital, providing evidence both that such firms are capital constrained and that local informal capital markets can successfully intermediate between local rural surplus and urban investment opportunities.

These findings have implications for many debates in development policy, although these applications are merely speculative. First, policies that increase agricultural production may also contribute to industrialization, although we must be cautious when applying findings from shocks to long term changes in productivity. Second, other policies that increase rural income, such as the Mahatma Gandhi National Rural Employment Guarantee Scheme (NREGS), may also increase industrialization. However, it should be noted that the increase in manufacturing employment that we observe occurs entirely in urban areas. This suggests that although manufacturing firms in rural areas may be credit constrained, returns in urban areas appear sufficiently high to overcome the proximity that rural firms have to the source of the income shock. Differences between returns to rural and urban manufacturing are certainly a topic for further inquiry.

Finally, our findings suggest that informal networks are able to intermediate capital between agricultural earnings and investment opportunities in manufacturing. However, at this point our evidence is mostly suggestive. Further research is needed to understand the channels by which agricultural surplus can fund urban manufacturing growth and the reasons that capital is able move from rural to urban areas within a district but is sufficiently localized to produce local growth, rather than being invested nationally. Although these informal markets do manage to facilitate manufacturing growth, it is necessary to understand the efficiency with which they are able to fund entrepreneurship in order to understand how well they can substitute for formal financial institutions.

Table 1

Construction of Primary Variables

Variable	Source	Description
Employment	Economic Census	Sum of employment of all nonfarm economic establishments in the Economic Census for each round (1990, 1998, 2005), including private firms, state-owned firms and government establishments (e.g. public schools).
Firm Count	Economic Census	Count of number of nonfarm economic establishments in the Economic Census for each round (1990, 1998, 2005), as defined above.
Rain	Indian Meteorological Department & ML Infomap	Demeaned and normalized measure of summer monsoon rain, defined as rain during the months of June, July, August and September. We match all villages to latitude and longitude using ML Infomap GIS data. We interpolate rainfall from grid points to the full village dataset of the 2001 Population Census. Subdistrict and district rainfall values are then computed as mean village rainfall, weighted by land under cultivation as given in the 2001 Population Census.
Agricultural income	Ministry of Agriculture & CMIE Indian Harvest	Sum of price $\times$ production for major crops at the district level, as reported by the Indian Ministry of Agriculture and compiled by the authors and CMIE. Missing prices are assigned using average state price for that year where available and average national price otherwise.
Infrastructure	Population Census	The village and town tables of the Indian Population Census (1991, 2001) provide measures of infrastructure (road, electricity, etc.).
Irrigation share	Agricultural & Population Censuses	The proportion of irrigated to non-irrigated land comes primarily from the Agricultural Census of 1995. Where missing it is provided first by the Agricultural Census of 2000 and if still missing from the 1991 Population Census. This proportion is then multiplied by land under cultivation as reported by the Indian Ministry of Agriculture and CMIE to get annual district-level land by irrigation status.

Table 2

Construction of Location and Industry Characteristics

Variable	Source	Description
Location classifications		
Bank90	Economic Census (1990)	Share of workers in location employed in the banking sector.
Market access	World Bank	Transportation costs from district centroid to nearest city of greater than 500,000 population in 2001 Population Census, as calculated using the Indian road network in Lall et al. (2004).
Industry classifications		
Tradable & Non-tradable	National Industrial Classification (2004)	Following Moretti (2010), we define tradable industries as all those falling under the manufacturing header (Section D)
Capital Intensity	Annual Survey of Industries (1991-2)	Total productive capital stock / total annual labor costs
External finance dependency	Annual Survey of Industries (1991-2)	Open loans / productive capital stock. Our best approximation of the measure used in Rajan and Zingales (1998).
Input Spending Shares	Input-Output Table (MoSPI)	Using the 2006-7 update to the 2004-5 Input Flow Matrix, we assign each $industry_i$-$industry_j$ pair an input share based on the percentage of non-labor and non-within-industry expenditure that $industry_i$ spends on inputs from $industry_j$. We then aggregate these for each industry based on the input of interest. For example, agricultural share is the by-industry share of input costs that go to agricultural products.
Tradability (CFS)	Commodity Flow Survey	The US Census Commodity Flow Survey gives average distance traveled per shipment by industry, which are then matched to NIC codes. Higher values mean more tradadable goods.

Table 3
Effect of rainfall shocks on district agricultural income
(annual, 1999-2004)

	1	2	3
Rain	5607.739	5933.648	
	(1115.639)***	(1116.941)***	
Rain^2		-3261.392	
		(857.973)***	
Rain AV125			6365.839
			(1248.261)***
District FE	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes
N	1524	1524	1524
r2	0.99	0.99	0.99

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$

Dependent variable is annual district agricultural income, as reported by the Planning Commission. Rain is defined as standard deviations from mean rainfall, with mean and standard deviations defined at the district level using the panel 1971-2005. Rain AV125 is defined as the absolute deviations from 1.25 standard deviations above mean, multiplied by -1 in order to make agricultural income increasing in the variable. All regressions have district and state-year fixed effects, with robust standard errors clustered at the district level.

Table 4

Effect of rainfall on rural employment growth

	1	2	3	4	5	6	7
Rain (sum)	0.004						
	(0.010)						
Rain_{t-1}		0.016					0.016
		(0.016)					(0.013)
Rain_{t-2}			0.002				0.000
			(0.030)				(0.028)
Rain_{t-3}				0.005			0.007
				(0.029)			(0.027)
Rain_{t-4}					-0.031		-0.037
					(0.019)		(0.021)*
Rain_{t-5}						0.036	0.043
						(0.034)	(0.034)
N	526	526	526	526	526	526	526
r2	0.38	0.38	0.38	0.38	0.39	0.39	0.39

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$

Dependent variable is rural district nonfarm employment growth, in logs. All regressions with state-year fixed effects and robust standard errors, clustered at the state level. Rain is defined as -1 × the absolute value of standard deviations of rainfall minus 1.25, considered the optimal amount of rainfall. Rain (sum) is summed over the five year period before the Economic Census. Period 0 thus corresponds to the five year window 1993-1997 and period 1 to 2000-2004. Rain_{t-n} is rainfall n years before the end of the Economic Census period. Control variables for all regressions are period land, urban and rural population, and share of employment in banking in 1990.

Table 5

Effect of rainfall on rural manufacturing employment growth

	NT	NT	T	T
Rain (sum)	0.002		0.007	
	(0.008)		(0.015)	
Rain_{t-1}		0.020		0.016
		(0.016)		(0.018)
Rain_{t-2}		0.001		0.004
		(0.029)		(0.043)
Rain_{t-3}		0.012		0.007
		(0.023)		(0.052)
Rain_{t-4}		-0.046		-0.026
		(0.026)*		(0.019)
Rain_{t-5}		0.039		0.041
		(0.037)		(0.039)
N	526	526	526	526
r2	0.44	0.45	0.31	0.31

$^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$

Dependent variable is rural district employment growth, in logs. Tradable employment (columns 3 and 4) is defined as employment in all establishments in the Economic Census with NIC codes falling under Section D (Manufacturing). Non-tradable employment (columns 1 and 2) is the sum of employment in all economic establishments not classified as manufacturing enterprises. All regressions with state-year fixed effects and robust standard errors, clustered at the state level. Rain is defined as -1 × the absolute value of standard deviations of rainfall minus 1.25, considered the optimal amount of rainfall. Rain (sum) is summed over the five year period before the Economic Census. Period 0 thus corresponds to the five year window 1993-1997 and period 1 to 2000-2004. Rain_{t-n} is rainfall n years before the end of the Economic Census period. Control variables for all regressions are period, land, urban and rural population, and share of employment in banking in 1990.

Table 6
Effect of rainfall on urban employment growth

	1	2	3	4	5	6	7
Rain (sum)	0.017						
	(0.006)***						
Rain_{t-1}		-0.003					-0.003
		(0.018)					(0.018)
Rain_{t-2}			0.039				0.032
			(0.024)				(0.024)
Rain_{t-3}				0.046			0.040
				(0.014)***			(0.012)***
Rain_{t-4}					-0.007		-0.011
					(0.021)		(0.020)
Rain_{t-5}						0.034	0.038
						(0.011)***	(0.012)***
N	526	526	526	526	526	526	526
r2	0.40	0.40	0.40	0.40	0.40	0.40	0.41

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$

Dependent variable is urban district nonfarm employment growth, in logs. All regressions with state-year fixed effects and robust standard errors, clustered at the state level. Rain is defined as -1 × the absolute value of standard deviations of rainfall minus 1.25, considered the optimal amount of rainfall. Rain (sum) is summed over the five year period before the Economic Census. Period 0 thus corresponds to the five year window 1993-1997 and period 1 to 2000-2004. Rain_{t-n} is rainfall n years before the end of the Economic Census period. Control variables for all regressions are period, land, urban and rural population, and share of employment in banking in 1990.

Table 7

Effect of rainfall on urban manufacturing employment growth

	NT	NT	T	T
Rain (sum)	0.010		0.034	
	(0.005)*		(0.013)**	
Rain_{t-1}		0.002		-0.015
		(0.017)		(0.033)
Rain_{t-2}		0.019		0.079
		(0.023)		(0.028)**
Rain_{t-3}		0.028		0.075
		(0.017)		(0.029)**
Rain_{t-4}		-0.011		-0.020
		(0.017)		(0.026)
Rain_{t-5}		0.022		0.070
		(0.016)		(0.024)***
N	526	526	526	526
r2	0.39	0.39	0.38	0.40

$^{*}p < 0.10,^{**} p < 0.05,^{***} p < 0.01$

Dependent variable is urban district employment growth, in logs. Tradable employment (columns 3 and 4) is defined as employment in all establishments in the Economic Census with NIC codes falling under Section D (Manufacturing). Non-tradable employment (columns 1 and 2) is the sum of employment in all economic establishments not classified as manufacturing enterprises. All regressions with state-year fixed effects and robust standard errors, clustered at the state level. Rain is defined as -1 $\times$ the absolute value of standard deviations of rainfall minus 1.25, considered the optimal amount of rainfall. Rain (sum) is summed over the five year period before the end of the Economic Census period. Period 0 thus corresponds to the five year window 1993-1997 and period 1 to 2000-2004. Rain_{t-n} is rainfall n years before the end of the Economic Census period. Control variables for all regressions are period, land, urban and rural population, and share of employment in banking in 1990.

Table 8

Impact of rainfall on employment growth by agricultural input intensity

	Rural	Rural	Urban	Urban
Rain	0.005	0.018	0.018	0.020
	(0.012)	(0.016)	(0.007)**	(0.007)**
High	-0.189	-0.356	-0.474	-0.505
	(0.078)**	(0.194)*	(0.068)***	(0.096)***
Rain × High		-0.025		-0.005
		(0.022)		(0.010)
N	1062	1062	1058	1058
r2	0.92	0.92	0.96	0.96

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$

Dependent variable is urban district nonfarm employment growth, in logs. All regressions with state-year fixed effects and robust standard errors, clustered at the state level. Rain is defined as -1 × the absolute value of standard deviations of rainfall minus 1.25, considered the optimal amount of rainfall, summed over the five year period before the end of the Economic Census period. Period 0 thus corresponds to the five year window 1993-1997 and period 1 to 2000-2004. High is a binary variable representing industries with agricultural input share of weakly greater than 0.2, determined using input-output tables. Control variables for all regressions are period, land, urban and rural population, and share of employment in banking in 1990. The coefficient on Rain therefore captures the effect of rainfall on employment growth in industries with agricultural input shares less than 0.2.

Table 9

Effect of rainfall on manufacturing growth by market access

	Low Trans Costs	High Trans Costs	Pooled
Rain (sum)	0.044	0.025	0.046
	(0.013)***	(0.023)	(0.012)***
Rain * High TC			-0.026
			(0.016)
High TC			-0.215
			(0.128)
N	245	277	522
r2	0.47	0.38	0.39

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$

Dependent variable is urban district employment growth in manufacturing establishments, in logs. All regressions with robust standard errors and state-year fixed effects, clustered at the state level. Rain is defined as -1 × the absolute value of standard deviations of rainfall minus 1.25, considered the optimal amount of rainfall, summed over the five year period before the end of the Economic Census period. Period 0 thus corresponds to the five year window 1993-1997 and period 1 to 2000-2004. High TC is a variable representing above median transportation costs from the district to the nearest city of 500,000 people (2001). Control variables for all regressions are period, land, urban and rural population, and share of employment in banking in 1990.

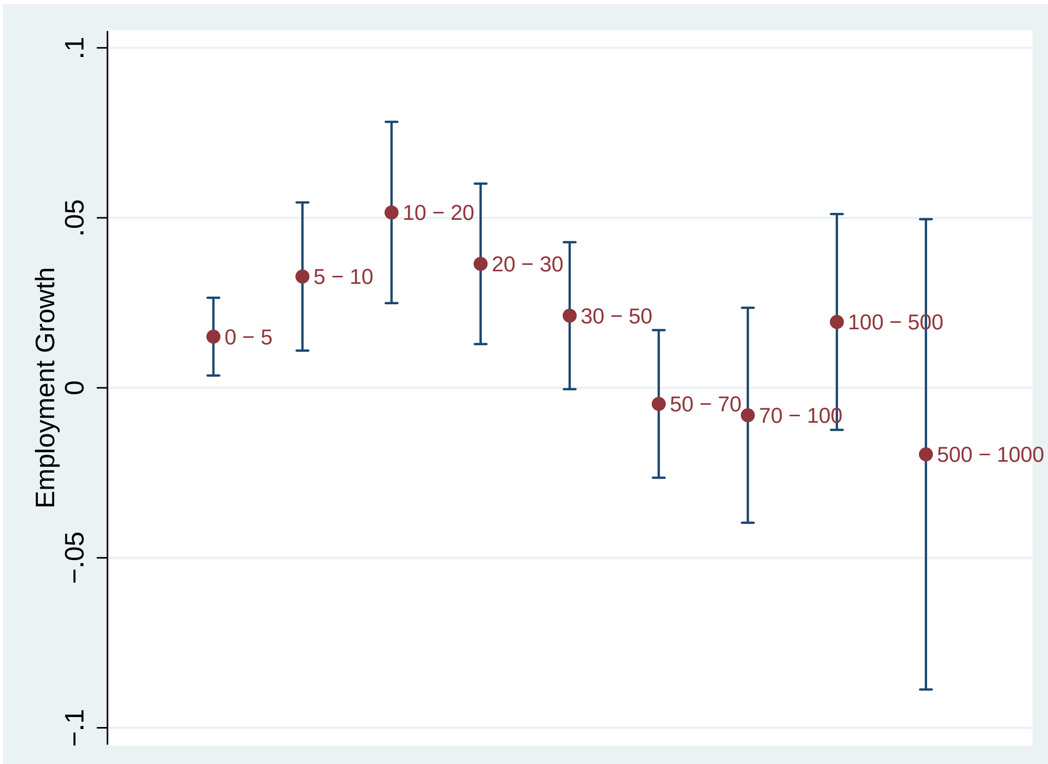
Table 10
Effect of rainfall on share of firms reporting informal financing

	Employment	Firm Count
Rain (sum)	0.005	0.005
	(0.002)**	(0.003)
Pop urban share	-0.085	-0.113
	(0.046)*	(0.056)*
Bank emp share	0.002	-0.003
	(0.012)	(0.010)
N	263	263
r2	0.43	0.60

$^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$

Dependent variable is change in share of establishments in the Economic Census reporting informal finance, 1998-2005. Firms receiving informal finance are those not reporting bank or government finance as the primary source of finance. All regressions with robust standard errors and state-year fixed effects, clustered at the state level. Rain is defined as -1 × the absolute value of standard deviations of rainfall minus 1.25, considered the optimal amount of rainfall, summed over the five year period before the end of the Economic Census period. Period 0 thus corresponds to the five year window 1993-1997 and period 1 to 2000-2004. Control variables for all regressions are period, land, urban and rural population, and share of employment in banking in 1990.

Figure 1
Effect of rainfall on growth by firm size



The figure plots the estimated coefficients of the reduced form regression of rainfall on urban employment growth (in logs) by firm size bins. Employment in a given bin is defined as the total employment in all economic establishments reporting the number of workers in a given range. The dependent variable is log growth of total district employment in a particular establishment size range, meaning that establishments at the beginning of a period are not necessarily in the same range at the end of the period. Growth in a particular bin may therefore come either on the intensive margin of establishments growing larger or on the extensive margin of establishments entering that size range. All regressions with robust standard errors and state-year fixed effects, clustered at the state level. Rain is defined as -1 × the absolute value of standard deviations of rainfall minus 1.25, considered the optimal amount of rainfall, summed over the five year period before the end of the Economic Census period. Period 0 thus corresponds to the five year window 1993-1997 and period 1 to 2000-2004. Control variables for all regressions are period, land, urban and rural population, and share of employment in banking in 1990.

Table 11

Effect of rainfall on growth by firm size

	5	10	20	30	50	70	100	500	1000
Rain	0.015	0.033	0.052	0.036	0.021	-0.005	-0.008	0.019	-0.020
	(0.007)**	(0.013)**	(0.016)***	(0.014)**	(0.013)	(0.013)	(0.019)	(0.019)	(0.042)
N	526	526	526	526	524	524	503	455	253
r2	0.42	0.33	0.66	0.44	0.45	0.40	0.46	0.52	0.43

$^{*}p < 0.10,^{**} p < 0.05,^{***} p < 0.01$

The dependent variable is log growth of total district employment in a particular establishment size range, meaning that establishments at the beginning of a period are not necessarily in the same range at the end of the period. Growth in a particular bin may therefore come either on the intensive margin of establishments growing larger or on the extensive margin of establishments entering that size range. All regressions with robust standard errors and state-year fixed effects, clustered at the state level. Rain is defined as -1 $\times$ the absolute value of standard deviations of rainfall minus 1.25, considered the optimal amount of rainfall, summed over the five year period before the end of the Economic Census period. Period 0 thus corresponds to the five year window 1993-1997 and period 1 to 2000-2004. Control variables for all regressions are period, land, urban and rural population, and share of employment in banking in 1990.

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