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The New and Changing Roles of Cold Storages in the Potato Supply Chain in Bihar[1]

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Abstract

There have been dramatic increases and rapid up-scaling of modern cold storages in Bihar, one of the poorest states in India and an area where smallholders dominate. These investments have been triggered by market reform, investment subsidies, and better overall public service provision and governance. Almost all potato farmers, small and large, participate in cold storages, the availability of cold storages is associated with improved efficiency in value chains because of lower wastages, and a number of these cold storages have become involved in input, output, and especially credit markets. The increasing availability of modern cold storages has therefore led to important changes in potato value chains, with significant implications for smallholders.

1. Introduction

Important changes are occurring in agricultural value chains in several developing countries (World Bank, 2007). These changes are noted upstream at the farm level, midstream with traders and processors, and downstream in retail markets (Reardon and Timmer, 2007; Reardon et al., 2012). Traditionally, especially technology changes and innovations upstream, at the farm level, have been the drivers for large productivity increases in agriculture and a large number of documented agricultural innovations have been linked to improved production technologies, better irrigation, improved seeds, and increased use of chemical fertilizers (e.g. Spielman and Pandya-Lorch, 2009; Evenson and Gollin, 2003). While innovations midstream and downstream in the value chain might also have significant impacts on agricultural performance, and might potentially benefit producers and consumers alike (Gardner, 1975), they have received less treatment in the literature and in policy discussions.

However, the subject has received more attention recently, e.g. Swinnen (2007), Dries et al. (2009), Reardon et al. (2009), Reardon et al. (2012). The debate on changes of value chains mid- and downstream has mostly focused on the implications of the rise in the consumption of high-value crops (e.g. Delgado et al., 2008; Gulati et al, 2007), the rapid emergence of modern retail and its impact (e.g. Reardon et al., 2009; 2012), and on the effect of food safety requirements for export agriculture from developing countries (Henson and Reardon, 2005; Maertens and Swinnen, 2009). However, few studies have looked at the effects of market changes midstream in traditional domestic value chains. We contribute to filling this gap.

We present in this paper the case of innovations and investments in post-harvest management and show how it is associated with important changes in traditional agricultural value chains in poor settings. More in particular, we document in this study the case of the rapid emergence and up-scaling of modern cold storage facilities in Bihar, one of the poorest states in India. In the districts studied, an area characterized by a large number of smallholders, the number of cold storages in the past decade more than doubled and rapid up-scaling of cold storages led to an even faster total capacity expansion, i.e. on average a four-fold increase over the same period.

These cold storages are almost exclusively used for the storage of potato, the most important vegetable (in volume) in India and in Asia more generally.

The fast emergence of such large modern players mid-stream raises important questions on the drivers and the implications of that change (e.g. Sarkar and Mitra, 2003; Nath and Chakrabarti, 2011). We address three questions in particular in this paper. First, we study the factors that have contributed to the rise of cold storage facilities. Second, we look at the role of the cold storages in the value chain and how it contributes to increased efficiency of the marketing system. Third, we study the use of and access to cold storages and analyze what types of farmers use these cold storages, how they use them, and what benefits participating farmers obtain from the availability of these cold storages.

To document the role that cold storages play, we rely on different sources of information. First, we conducted key informant interviews with several stakeholders in the value chain. Then, we implemented a detailed structured questionnaire with the different agents in the value chain including cold storage owners, producers, local collectors, wholesalers, and retailers. This gives us unique insights on the role that the cold storages play. Such primary surveys are innovative, especially in the context of value chains in India, and developing countries more broadly, where the debate has been hampered by the lack of quantitative evidence and analysis (e.g. Basu, 2010; Moazzem and Fujita, 2004; CII/McKinsey, 2013; Hellin and Meijer 2006; Nang'ole, Mithöfer, and Franzel 2011).

The structure of the paper is as follows. In Section 2, we describe the study area and the data collection methodology. Section 3 illustrates the expansion of the cold storages over time. In Section 4, we dwell on the triggers for the rapid diffusion of the cold storages. Section 5 then looks at the role of the cold storages, not only for storage behavior but also for the other services delivered. In Section 6, we document storage behavior of farmers, the cost of storage in the value chain, and wastages. We finish with the conclusions and implications in Section 7.

2. Case study area, data and methodology

2.1. Background

Potatoes are an important crop in India. India is ranked third in production in the world after China and Russia. Potatoes are estimated to be the largest vegetable crop accounting for 23% of all area planted under vegetables (Kumar, 2009). Potato consumption is widespread in India and it is estimated that it is consumed by 92% of all Indians (Das Gupta et al., 2010). Annual consumption was evaluated at 18 kgs per person per year in 2007 (Faostat). Das Gupta et al. (2010) report that potato processing is limited: the share of fresh potatoes in potato consumption is about 95% and the importance of processed potatoes (for chips, French fries, etc.) is still minor (5%).

A major challenge in India is potato storage as potato production that takes place in the cold months of October-November to February-March (about four-fifths of total production) is followed by hot summer months; this makes refrigeration necessary for storage.[2] Cold storage takes place on a large scale. It is estimated that there were about 3,400 cold storage facilities in the beginning of the 2000s in India (CIP, 2006) but they had increased to 5,386 units in 2008 that could store over eighteen million tons of crops (www.Indiastat.com).[3] Most of the cold storages in India are used towards potato storage. CIP (2006) estimates that approximately three-fifths of potatoes in cold storages are table potatoes, intended for consumption, while the other two-fifths are used for seed. Using average storage fees from our survey (and assuming 80% of cold storage use by potatoes), it is estimated that about 0.4 billion USD is spent yearly by traders and farmers on storage for these potatoes in India, indicating the considerable size of this business.

Bihar, the state where the study was done, is considered one of the lagging states in India. Its per capita income, at about 160$, has been one of the lowest in India (World Bank, 2005). However, its performance seems to have improved in recent years and Bihar registered between 2005 and 2010 one of the highest economic growth rates at the Indian state level. But poverty levels in Bihar are still high and about 37 million of its 90 million people are estimated to be poor (World Bank, 2007). Bihar is largely an agrarian state, with agriculture still employing 80% of the workforce and contributing 42 % of the state domestic product (Choudhary, 2011). The landholding pattern in the state reflects the small-holding character of the state's agriculture, with small and marginal farmers accounting for 92% of the total land holdings and 60% of the total operation land holdings and with an average size of landholding at around 0.6 hectare.

2.2. Data collection

Though the farmers in all 38 districts in the state grow potato, Vaishali and Samastipur - where the surveys were fielded - figure prominently as major potato producing districts in the state (Singh and Rai, 2011).[4] Both districts are located in the northwestern alluvial plane zone. While Bihar is overall blessed with highly fertile land and good quality water resources, low agricultural productivity has been a major problem. Moreover, there are issues with water supply in these districts: Vaishali and Samastipur have only 39% and 43% respectively of their land under irrigation. These rates are lower than the state average of 54%.

Different types of surveys were set up by our research team to understand the role of cold storages, storage behavior of farmers, and the role of storage in potato marketing in Bihar. They included surveys with potato producers, village heads, wholesalers, retailers, and cold storage operators. This survey set-up reflects the structure of the potato value chain. Farmers sell potatoes; cold storages sell storage and other services; wholesalers sell logistics, grading and sorting, and marketing services; and retailers sell the final product. Cold storages only play a role in the value chain in off-season marketing as fresh potatoes are sold directly to wholesalers who then sell to retailers. In the off-season, farmers themselves often pay for storage in cold storages although some traders buy up the produce at harvest time and sell after storage. The structure of the value chain dictates the survey methodology as the purpose was to follow prices, products, and services throughout the rural-urban chain, during the fresh potato season as well as in the off-season and from rural producer to urban consumer.

The village and household survey was set up as follows. For potato farm households, the most important potato producing *tehsil* - in terms of quantities produced - in each of Vaishali and Samastipur was selected. Given that Samastipur is a bigger potato producing area than Vaishali, more villages were selected in the former.[5] In each selected village, a village questionnaire was implemented and a census of households was conducted to enumerate the potato producers. Using the census questionnaire, a list of all the potato producing households in the village was made. Each household was asked questions on its total land cultivation and potato cultivation in particular and if it was a seller of potato. Eighteen potato producing households were then randomly selected in each of the 14 villages, half from the stratum of larger farms (more than 1

acre of potato cultivation) and half of them from the stratum of smaller farms (less than 1 acre of potato cultivation). 252 potato farm households were thus interviewed in total.

The trader survey and cold storage surveys were set up as follows. First, two village trader/collectors were randomly selected from those that were active in the selected villages and were then interviewed. Second, 30 traders were interviewed from the local wholesale market in the district. Third, 20 urban wholesale traders and 164 retailers in the capital Patna were randomly selected and interviewed.[6] To implement the cold storage (enterprises) survey, a list of all the cold storages in the district of Samastipur/Vaishali was obtained from the Horticulture Department. A random selection of 27 was done and detailed surveys were conducted. For all cold storages that were not visited for a detailed survey, the date of establishment was collected through key informant interviews. We also collected data on cold storages that ceased operations. This information allows us to analyze their net growth over time.

2.3. Descriptive statistics

We first present some descriptive statistics on the different surveys implemented. The potato farmers in the survey are on average 53 years old (Table 1). They have a household of about 7.4 family members and 98% of the heads of households are reported to be male. 10% of the heads of potato farming households are illiterate, significantly lower than the average at the state level: 53% of the population was estimated to be illiterate in the national census of 2001. This indicates that these farmers are relatively better endowed than other farmers in Bihar. The (imputed) value of all the land of these farmers – their most important asset – is estimated at 2.6 million Rs (or 59,000 USD).

Table 1: Farmer profile

Potato farmers that were selected in these two districts are in general small, as they only cultivated 2.23 acres in total (potato plus other crops), of which 0.95 acres on average are allocated to potatoes (Table 2). An average potato farmer in these districts cultivates 3.2 potato plots. 90% of the cultivated potato land is owned by the farmer and 10% of the land is rented in. An average farmer sold 5.3 tons of potato in the year prior to the survey. Most of the produced potatoes are used towards sales, indicating the importance of potatoes as a cash crop for these

households. About two-thirds of the potato output is sold while 30% is kept towards seed use and own (home) consumption. It is estimated by the households that 5% of the production of the year prior to the survey was wasted before, during, or after storage.

Table 2: Potato farming profile

Table 3 shows some survey statistics of the other value chain agents that were interviewed. 27 cold storage owners, 65 wholesalers, and 164 retailers were interviewed in total. The results show the significantly larger capital that cold storages have at their disposal compared to other value chain agents. The value of a cold storage in the surveyed region amounts to about 50 million Rs. This compares to a value of assets (and working capital) of 56,570 Rs (153,430 Rs) for wholesalers and 8,600Rs (19,300Rs) for retailers. Of all agents in the value chain, the retailers have least capital at their disposal for their business (with average assets as low as 8,600 Rs). The turnover of wholesalers is estimated to be almost five times as much as that of retailers, i.e. 635 and 130 kgs per day respectively.

Table 3: Descriptive statistics agents value chain surveys

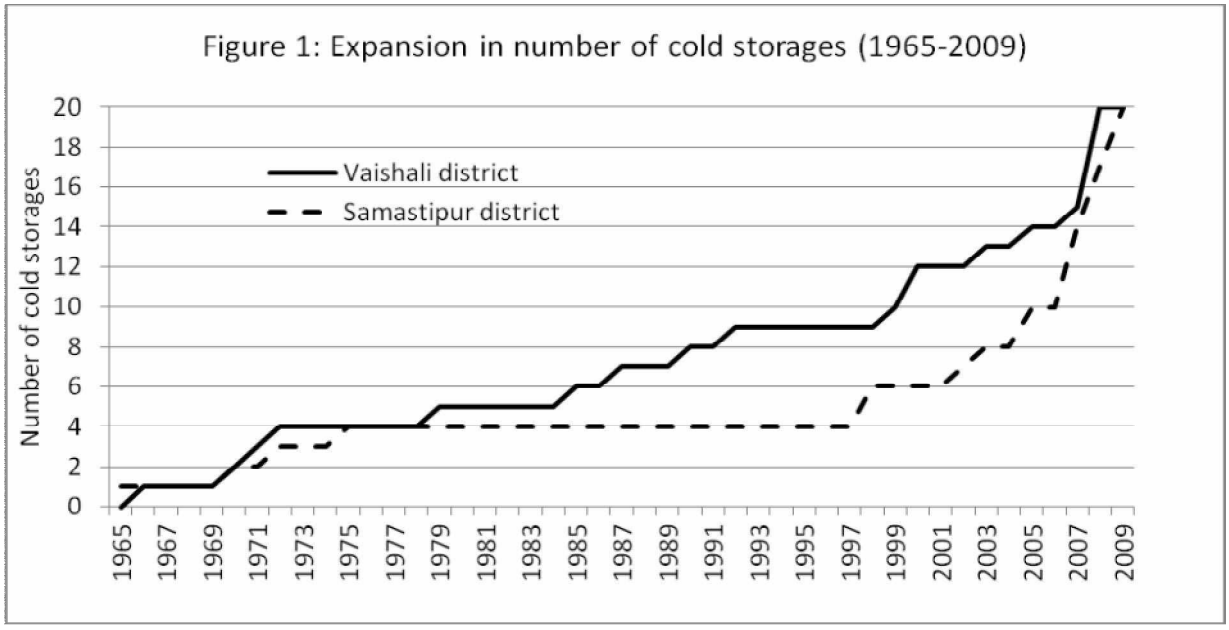
3. Bihar's potato sector and the emergence of cold storages

Although there are questions on the reliability of official production statistics of potatoes, the National Horticulture Board (NHM) indicates that Bihar is the third biggest potato producing state in India, coming after Uttar Pradesh and West Bengal. In 2007-08, it was estimated that the biggest producing state was Uttar Pradesh with a share of 32.2%; second was West Bengal with a share of 28.7%, and third was Bihar with a share of 19.1%, producing just above 6 million tons. The average yield in Bihar was evaluated in official statistics in 2007-08 at 19.1 tons per ha, equal to the Indian average. Yields in the survey districts range from 18.9 (Vaishali) to 20.4 (Samastipur) tonnes per ha (Singh and Rai, 2011), similar to state levels.[7]

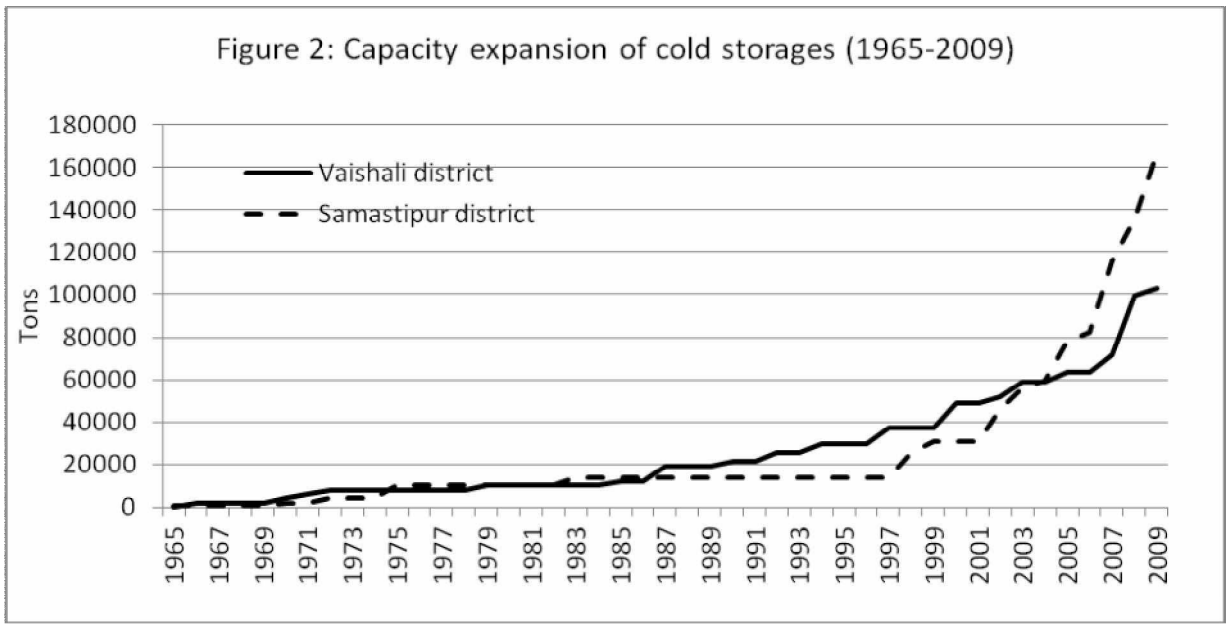
Building on a list of cold storages obtained from the National Horticultural Board, we evaluated through key informant interviews, as well as formal surveys, the evolution in the number and the capacity of cold storages. We estimated that the number of cold storages at the state level in Bihar increased between 2000 and 2009 from 195 to 320, an increase of 64% over the whole period or an annual increase of 5.7% (using a compound annual growth rate method).[8] Figure 1

shows the expansion of such cold storages in the two studied districts in particular. It shows that there were 20 cold storages in each of the districts at the time of the survey. The graph shows how the growth of the cold storages has mostly happened in the past decade, or even more recently. The district of Samastipur only had 10 cold storages in 2005 but this doubled since then. Before 1998, there were only 4 cold storages in this district. The growth in the district of Vaishali was much smoother as cold storages 'only' doubled in the last decade.

While the number of cold storages increased dramatically, these graphs do not take into consideration expansion of the existing cold storages. As we implemented a survey with the cold storages and questions were asked on their capacity expansion over time, this allows us to calculate complete capacity expansion in these two districts. The average capacity per cold storage was between 1,000 and 2,000 tons in the beginning of the 1970s but at the time of the survey, the average capacity had grown to 5,142 tons in the district of Vaishali and 8,350 tons in the district of Samastipur. Combining the growth of capacity per cold storage with the total number of cold storages gives the total cold storage capacity expansion in the two districts. As expected, the results (Figure 2) show an even more dramatic increase than in the previous graph. In the past decade, total cold storage capacity expanded almost three-fold in the case of Vaishali while it expanded more than five times in the case of Samastipur. Total cold storage capacity in 2009 was just over 100,000 tons in Vaishali and about 170,000 tons in Samastipur. When all capacity of the cold storages would be used, this involves an approximate yearly business or revenue of just below 10 million $ in the two districts combined.[9]



Source: Authors' calculations



Source: Authors' calculations

Based on in-depth discussions with owners, several factors were identified that contributed to the boom of cold storages in these two districts. The triggers relate to the provision of public goods

by the state government, policy reform, subsidies towards cold storage investments by the national and state governments, and the availability and spread of new technologies.

The first trigger was a series of improvements in the past decade in public good provision and in policy reform in Bihar that created a better business and enabling environment which allowed the boom to happen. Three factors were crucial. First, deregulation of the sector seems to have given an important impetus. Key informants indicated that there were few cold storages in both the districts in the regulated period of 1960s through 1980s but they were hardly sufficient to meet the demand, which often led to a scramble among the farmers for space in the cold storages.[10] During this regulatory period, cold storages were supposed to be used only for seed potatoes. Each cold storage was assigned a certain number of blocks by the district Horticulture Department, with the number of blocks assigned to be determined by the capacity of the cold storage. Getting storage space in the cold storage was an onerous task for a farmer in that era as he/she had to submit his/her land documents to the block officer who would then verify his/her area of potato cultivation and assign a cold store space quota, based on the seed requirement of the farmer.

Moreover, instead of amending its own Agricultural Produce Marketing Act (APMC) act in line with the Model APMC Act proposed by the Central Government, the state government of Bihar completely privatised its agricultural marketing infrastructure by repealing the Act in 2006. This had significant implications for both the marketing of potatoes and the use of cold storages. The erstwhile act mandates that the sale and purchase of potatoes can only be conducted by commission agents licensed by the state government in the regulated wholesale markets. However, such restrictive clauses were removed following the repeal of the act, facilitating the emergence of the cold storages as new hubs of marketing activity in the state.

Second, Bihar has suffered from a lack of public infrastructure provision, such as electricity and roads, and has been ranked poorly with the rest of India on this. However, the government that came to power at the end of 2005 in Bihar has made significant investments in road infrastructure, improving the marketing of agricultural products from the more remote and disadvantaged districts. Making improved road infrastructure as one of its key priorities, the state government planned that it would spend more than 3 billion USD on road construction in three

years (Government of Bihar, 2006). It has been estimated that between 2006 and 2012, about 17,000 kilometers of roads were built. This compared to 295 km for the period from 2001 until 2005 (Aiyar, 2013).

Third, Bihar has been characterized by a lack of law and order, discouraging businesses from starting up and locating, especially in rural areas (World Bank, 2005). This seemed to have changed in recent years. There was a mass jailing of criminals, leading to less insecurity. For example, there were 514 incidents of violent crimes during the period of 2006-2010. This compares to 1,309 for the period 2001-2005 (Aiyar, 2013).The number of kidnappings with ransom demands further declined from 411 in 2004 to 57 in 2012 (Aiyar, 2013).

The second trigger was provision of subsidies by the Indian government in an effort to stimulate innovation in the horticultural sector. In its 1999-2000 budget, the Central Government proposed a major subsidy scheme for the construction of cold storages. It is estimated that between 1999/00 and January 2005 the National Horticultural Board (NHB) provided Rs 3.1 billion for the establishment of 1,242 cold storages, covering 23 states (Patnaik, 2005). This helped expand cold storage capacity by 4.9 million tons nationally.[11] The cold storages in Bihar started receiving the subsidies later than the rest of the country, due to the reluctance of the state government to change its Cold Storage Order. On top of the subsidies of the center, the new state Government gave additional incentives designed to stimulate rapid diffusion of cold storages. In addition to the 25% subsidies given by the NHB for new investments, the state government promised another 15% subsidies, including 10% by the State Industrial Promotion Board.

The third trigger was the availability and spread of new technologies at the farm level as well as for cold storages. First, the introduction of high speed compressors in the cold storage operations in the beginning of the years 2000 meant that less time was required to bring down the temperature and that electricity consumption was significantly reduced, which according to some of the interviewed owners, led to a reduction of cost of operation by almost 20 to 30%. Second, investments were done by the research and extension system as to improve the spread of potato varieties that were apt for storage given that the traditional red potato that was commonly grown in Bihar was much more difficult than most market varieties of white potato to store for long periods.

4. Role of the cold storages

4.1. Storage behavior

Cold storage owners were asked questions in our survey on the type of people that store potatoes in the cold storage (Table 4). About 2,245 people store potatoes in an average cold storage. Interestingly, 91% of the users of cold storages are farmers. An average cold storage contained in the past year almost 100,000 50 kg bags. While two-thirds of the stored bags belonged to farmers, 31% belonged to traders, indicating that the average quantity stored by traders is significantly higher than by farmers: an average farmer stored 33 bags; this compares to 144 bags on average per trader. The number of bags stored by the cold storage owner himself is estimated to be significantly less important.[12]

Table 4: Characteristics of cold storages

Storage behavior is changing quickly over time, as already seen in Figures 1 and 2. First, we see an important process of up-scaling of the surveyed cold storages (Table 4). While a cold storage was holding 4,200 tons at start-up (on average in 1996), this had increased to 6,300 tons at the time of the survey. If a cold storage was started up before 2000, its storage capacity was on average only 3,600 tons. If started up after 2000, this was as high as 5,100 tons. Second, the type of potatoes that are stored has changed. While more than two-thirds of all potato storage 10 years ago was towards seed potatoes, this has now been reduced to about half of the potatoes in storage (Table 5). The other half of the potatoes are now stored towards sales as table varieties, indicating the increasing commercialization of potato in these districts. This increase seems to lead to an increasing importance of the role of traders (and cold storage owners) over time in potato storage, e.g. while traders owned 8% of all stored potatoes in 1999, this share had increased to 16% in 2009.

Table 5: Evolution in storage behavior over the last decade

4.2. Other services

The emergence of the cold storages might not only have obvious implications on better storage conditions of the potatoes, and thus leading to lower wastages overall in the value chain (see

later) but also have de-seasonalized the consumption of potatoes over time. Given deregulation, the increasing spatial spread of cold storages, and the more intense competition between them, cold storages are seemingly becoming more involved in potato input and output markets, offering more services to farmers (Das Gupta et al., 2010).

Cold storage owners were asked questions on the (non-storage) services that they provide to the farmers (Table 6). While some cold storages arrange access to potato seeds, chemicals, and pesticides for some farmers, the importance of this service seems still very limited (8% of the cold storages). Few cold storages also provide advance payments before storage or extension services. However, the large majority of the cold storages (80%) provide credit to the users that store there, using the potato bags as collateral. It is estimated by the cold storage owners that they gave credit to 25% of the users of their cold storage. When taking into account the size of the cold storage, this percentage is as high as 29. The credit given per bag is uniform for all the cold storages in the sample and amounts to 50% of the value of a bag of potato. Most storage owners reported that they have a link with a bank to provide for this credit.

Cold storage owners are also involved in output market linkages. More than half of the cold storage owners reported that they contacted buyers and arranged transactions with users of the cold storage on their behalf. It is estimated that in the cold storages where the owners did provide these services, about 40% of the cold storage users would use these contacts. Most of the cold storage owners (93%) reported that they would not ask any commission for this. Half of the cold storages also offered grading and sorting services. Some of them were further involved in providing transport services from farm to cold storage (5%) and from cold storage to buyers (11%). These numbers thus illustrate that these cold storages provide services in the potato sector that largely go beyond the storage function, but they seem to be doing this less in Bihar than found in Uttar Pradesh (Das Gupta et al., 2010), possibly because of their relatively recent rise in Bihar.[13]

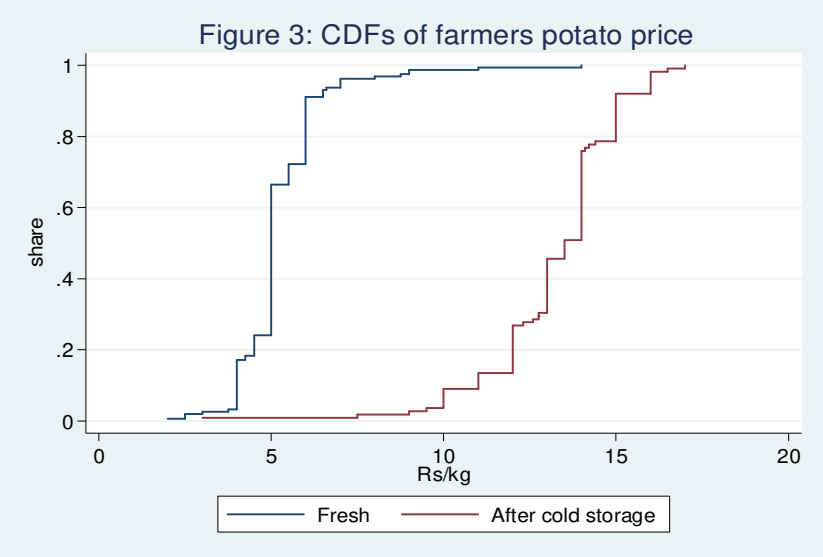
Table 6: Services provided by cold storages

5. Cold storages and the potato value chain

5.1. Farmers' participation in cold storages

Detailed information was asked on farmers' storage behavior in the year prior to the survey. 92% of the farmers reported that they had stored potatoes in 2009. For those who did not store potatoes, they mostly reported that they could not store because they needed money urgently after the harvest. For those that stored, they reported to have mainly done so because they expected the price of potatoes to rise (35%) or because they were storing for seed potatoes (62%). All the farmers that stored potatoes in 2009, used cold storages to do so and traditional on-farm storage methods – except for use over short periods - have apparently disappeared.

Figure 3 shows cumulative density functions for sales prices in the harvest period and after cold storage. They show that the prices after cold storage dominate the harvest period prices by a significant margin over the whole domain. 96% of the reported prices at the harvest period were below 7 Rs/kg while 99% of the sales prices after cold storage were above that level in the off-season period. This shows the extent those farmers that were able to postpone sales benefited from doing so, as the benefits of doing so far outweighs the costs (the monetary cost of cold storage is about 1.5 Rs/kg).



Note: CDFs=Cumulative Density Functions

As the timing of the sales might just be one factor among many that determine price setting, we present the results of a price regression with other potential determinants as explanatory variables in Table 7 so as to better understand which other factors are potentially associated with

price performance in this environment. The results confirm that those farmers that are able to postpone sales until after cold storage obtain a significantly better price than those who sell immediately after the harvest. Farmers who sell bigger quantities are also able to negotiate better prices. A doubling of the quantity sold leads to a significantly higher price of 0.19 Rs per kg. None of the other included factors in the two specifications of the regression shows a significant effect.

Table 7: Price determinants

To illustrate how farmers spread their sales over time and who benefits from these higher prices in the off-season, we calculate the importance of sales for small and large farmers over the course of the year, simply aggregating sales over the (un-weighted) sample. For the sampled farmers, it is estimated that about 55% of the potatoes are sold fresh (defined as the period from February until June) and 45% of the sold potatoes have gone through cold storage (from July until November). Small as well as large farmers sell a significant portion of their potatoes fresh as well as after cold storage. However, the importance of the sales in off-season is relatively more important for the larger farmers. While the quantities sold in fresh and cold storage periods are the same for the large farmers, small farmers sell only half of the total quantity that is sold in the fresh period in the off-season.

Given the importance of the timing of the sales for farmers' prices, we like to understand better the determinants that are associated with sales after cold storage. To analyze this, we build on the empirical framework of Fafchamps and Vargas-Hill (2005).[14] The dependent variable takes on a value of one if the farmer sold after cold storage and zero otherwise. We estimate probit models given the binary nature of our dependent variable. Standard errors are estimated after accounting for within-cluster (village) correlations and possible heteroskedasticity. A district dummy variable is included to control for possible location-wise unobserved heterogeneity.

In the first regression reported in Table 8, we present the results of a standard probit regression. Two variables are included that are assumed to be linked with sales after storage, i.e., wealth (because of different time preferences), as measured by the land owned by the farmer, his/her most important asset as shown in Table 1, and the quantity sold (because of changes in transaction costs).[15] The results indicate that an increase of wealth of the farmer has an important

significant effect on the timing of the sale. The quantity of the sale is not associated with the timing of sales. In a second regression, we control for possible omitted variables. In this specification, the wealth variable still stays largely significant. Another variable that comes out significant is a dummy variable that measures if the head of household has access to a source of off-farm income. Those farmers that have such sources are more likely to postpone their sales. This might indicate that those households might be less driven by liquidity constraints to do their sales. None of the other variables are significant.

As it can be argued that the quantity sold is endogenous to the time of sale (as stored produce is usually taken out at once, generating large quantities for sale), we instrument the quantity sold in the transaction by using the total quantity sold by the household as an instrument as done by Fafchamps and Vargas-Hill (2005). This instrument is valid as shown by the significant results of an F-test at the bottom of the Table. We follow the approach suggested by Smith and Blundell (1986) and River and Voung (1988) and include the residual of the instrumenting regression in the second stage regression. The significance of the coefficient on the residual provides a test of the endogeneity of the quantity sold. In this specification, most of the determinants come out not significant. However, the coefficient on the residual of the instrumenting regression is not significant indicating that we do not have an endogeneity problem in our specification. We thus proceed with un-instrumented specifications.

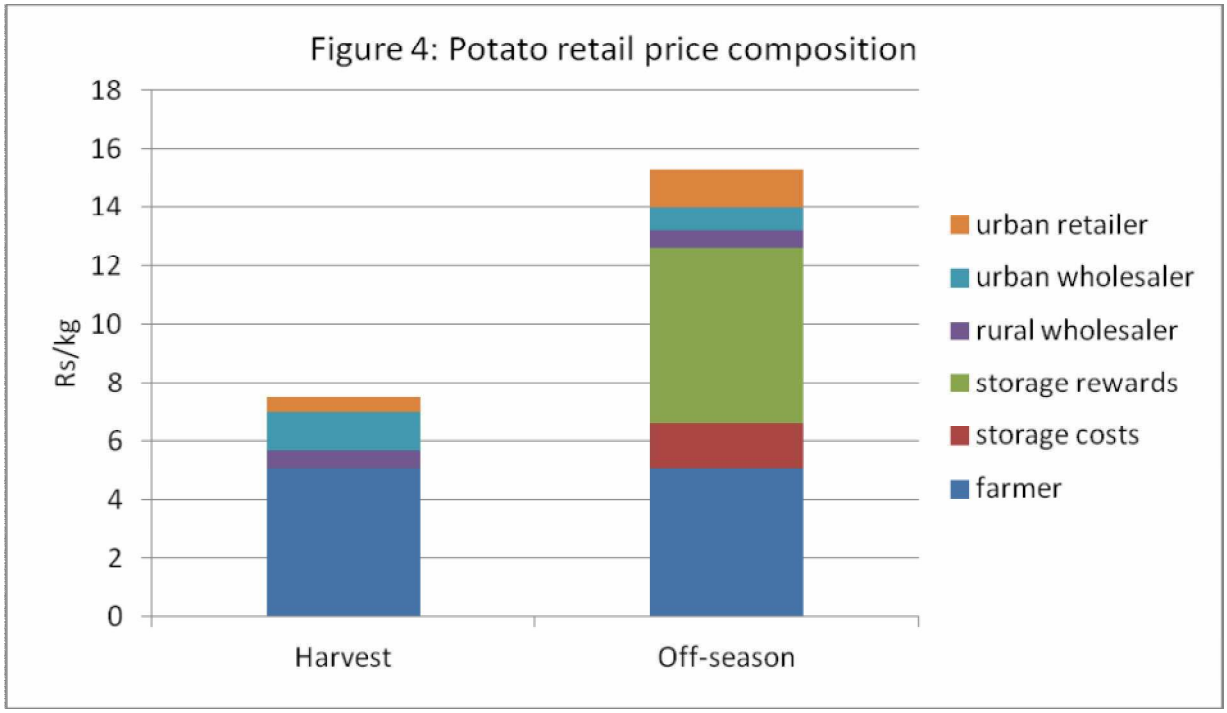
In two further regressions, we interact the wealth of the household with the quantity sold. In this case, we find that the richer the households and the more it has to sell, the more likely it will postpone the sales of potatoes until after cold storage. These results hold even when we control for different other factors that might be related to the timing of the sales. Based on the descriptive as well as the regression analysis, we thus conclude that the wealthier farmers use cold storages significantly more as to capture the benefits of the price rise of potatoes in the off-season.

Table 8: Determinants of sales transactions after cold storage

5.2. Cost of storage in the value chain

Questions were asked on the price evolution over the past year at different points in the value chain (producers, cold storage owners, wholesalers in urban and rural areas, and urban retailers in Patna where a significant part of the commercial potatoes were sold). This information allows us to de-compose the final retail price and to evaluate the size of the margins in the value chain. Figure 4 shows the potato price evolution in the 12 months prior to the survey at each level of the value chain as calculated from recall questions from a representative number of interviews at each level. As commonly is the case, prices rise after the harvest period due to storage costs and the opportunity costs of money. In the 2008-2009 season, potato retail prices in Patna rose by more than 100%, from a low of 7.5 Rs/kg during March to a high of 15.3 Rs/kg during September.

It is estimated that during the harvest period, the share of the producer in the two districts interviewed in the final consumer price in Patna was 68%. The cost of marketing a kg of potatoes from producers to urban consumers was about 2.4 Rs/kg during that period. The share of producers that were willing and able to store potatoes for sales increased to 82% of the final price by the month of September, the month when most of the potatoes that were held in cold storages are taken out. This share is significantly higher than those conventionally found in horticultural value chains in India. This might reflect the better options that potato producers have as they are not obliged to sell immediately, in contrast with other more perishable crops, given potatoes' longer shelf-life. The results further show that the storage costs are only a minor cost in the potato value chain. These costs counted for less than 10% of the final retail price that the consumer in Patna paid for the potatoes in the off-season. The Figure further shows that a big share in the final retail is explained by the rewards to storage, accounting for 40% of the final retail price.



5.3. Wastage in the value chain

The conventional wisdom is that the traditional supply chain for staples in India is necessarily mired in high rates of wastage. For example, Mattoo et al. (2007) find that the average losses in horticulture overall and potato value chains are as high as 12% and 11% respectively. They also mention that "According to one study, India wastes more fruits and vegetables than those consumed in the UK" (ibid, p. 43). Singh (2012) reports losses in the potato value chain in Uttarakhand at 12% (but unfortunately, he has no such data for Bihar). Others put wastage of horticulture crops much higher, i.e. between 20% and 40% (CII/McKinsey, 1997, 2013; Mittal, 2007). In Bihar, the World Bank (2007) estimates the wastage in the potato value chain at 24%. However, in all cases, estimates are not based on representative reliable surveys.[16]

To get at the level of total wastages in potato value chains, we asked all the different agents in the survey (with a survey in each segment of the value chain) how much was wasted in storage, between the process of obtaining and selling potatoes, and during their last transaction when potatoes might have been transported. This gives us a reasonable approximation of the total waste in the value chain. We find that the total quantities of potatoes wasted, and not used for

consumption, are equal to 8.0% in the harvest period and 9.3% in the off-season of all the quantities that enter the value chain (Table 9). Such a performance might even be better than developed countries, where quality and cosmetic criteria are more severe (Kader, 2005; Parfitt et al., 2010). While some have argued that the cuts in electricity in Bihar leads to major losses for potato cold storage, in our surveys, all cold storages have diesel generators that keep the storages cool at times of electricity cuts, at admittedly higher costs. Because of the availability of cold storages, wastage levels seem to have come down as these wastage numbers are significantly lower than those done in some previous estimates, although previous estimates were not based on detailed surveys in each segment of the value chain, as we have done (World Bank, 2007).[17]

Table 9: Wastage in the value chain

6. Conclusions and policy implications

We document in this study the rapid emergence of cold storages in poor districts in Bihar, an area characterized by a large number of smallholders. In the two districts that were studied, the number of cold storages in the past decade doubled in one district and tripled in the other one and rapid up-scaling of cold storages led to an even faster total capacity expansion, i.e. a triple and five-fold increase over the same period. We find that the spread of the cold storages in these districts has been driven by a multitude of factors related to policy reform, the improved provision of public goods (road infrastructure and governance), the availability and spread of new technologies within the cold storage sector, as well as by subsidies by the government.

The increasing spread of these cold storages has led to a large part of local potato production going through it, for local seed use by farmers as well as for sales. Cold storages are associated with improved efficiency of the marketing system because of lower wastage in the value chain. While almost all farmers use cold storages, larger farmers (although still relatively small by global standards) participate more towards storage for sale as to benefit from higher prices in the off-season and they are then able to capture a higher share of the final consumer price. Smaller farmers benefit more through the cheaper and more reliable storage of seed potatoes. Because before potatoes were stored on-farm using traditional storage methods (see Katana et al., 1997), we thus show that market innovations and modernization, through the spread of modern cold

storage facilities can be important drivers for better agricultural performance even in poor settings.

The emergence of these modern cold storages raises questions on implications for different groups of farmers. While we find that the small potato producers participate less so for the storage of potatoes for sale, they also seem to have benefited from the diffusion of cold storages. First, the evidence in this paper shows that a large number of even relatively small farmers participate directly in the cold storages. Because of better storage conditions of their seeds, they benefit directly from the existence of these cold storages and from the existence of this extra market channel. Second, small farmers that do not participate in cold storages can still gain from the existence of these. As prices are smoothened due to the availability of an extra marketing channel (the storage option), it can be expected that prices increase, on average, during the harvest period (Fuglie, 1995). For those smaller farmers that sell relatively more directly after the harvest, they therefore benefit from these higher prices.

The results of our study also point to a number of policy implications. First, more competition in the cold storage sector is desirable so as to drive down the cost of storage. As capacity use was high during a year when potato production was bad, as storage charges were still relatively high, and as profitability rates are substantial, there is a need for further investments in this area in Bihar to ensure a more competitive environment. While the subsidies that were given out by the government have helped to stimulate the setting up of cold storages in Bihar, it has however not (yet) led to the lower storage costs that one would expect. Second, the spread of cold storages as intermediaries in the potato value chains might also open some important opportunities towards improvements of the potato value chains as cold storages can serve as focal points for the distribution of better seed varieties, extension advice, and marketing opportunities.

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Table 1: Farm profile

		Statistics	
	Unit	Mean	Median
Number of observations	Number	256	
Background information household			
Age head of household	Years	53	55
Household size	Number	7.4	7.0
Gender of head of households	% male	98	
Illiterate heads of household	%	10	
Land and assets			
Land owned and cultivated	Acres	2.02	1.29
Land owned but cultivated by another household	Acres	0.10	0.00
Rented in land or received for free	Acres	0.21	0.00
Total operated land	Acres	2.23	1.53
Number of plots cultivated	Number	9.5	7.00
Value of land owned	1000 Rs	2,660	1,592
Value of livestock assets	1000 Rs	40	21
Value of farm assets	1000 Rs	47	13

Table 2: Potato farming profile

		Statistics	
	Unit	Mean	Median
Number of observations	Number	256	
Potato activities			
Potato land:			
Land owned and cultivated with potato	Acres	0.85	0.55
Rented in land or received for free cultivated with potato	Acres	0.10	0.00
Total potato land cultivated	Acres	0.95	0.55
Number of potato plots cultivated	Number	3.2	3.0
Was growing potatoes ten years ago	%	87.3	
Use of potato production:			
- own consumption/seed use	%	30	
- wasted	%	5	
- sales	%	65	
- total	%	100	
Total potato sales in 2009	Ton	5.3	1.7

Table 3: Descriptive statistics agents value chain surveys

	Unit	Mean	Median
Cold storage			
Number of observations	Number	27	
Capacity of cold storage	Tons	6,288	6,000
Value of cold storage	1000Rs	51,596	48,157
Wholesalers			
Number of observations	Number	65	
Quantities procured daily*	Kgs/day	635	170
Value of assets	1000 Rs	56.6	10.9
Working capital	1000 Rs	153.4	87.8
Traditional retailers			
Number of observations	Number	164	
Quantities procured daily*	Kgs/day	130	
Value of assets	1000 Rs	8.6	1.3
Working capital	1000 Rs	19.3	10.0

* ; Averaged over the year

Table 4: Characteristics of cold storages

	Mean	Median
Number of observations	27	
Overall information		
Year of start-up	1996	1998
Storage capacity (in tons)	6,288	6,000
Storage capacity (in tons) at start-up	4,272	3,500
Storage capacity at start-up (in tons), if started up before 2000	3,672	3,000
Storage capacity at start-up (in tons), if started up after 2000	5,145	6,000
Current value of the cold storage - millions of Rs	54	50
People that store in cold storage		
Number of farmers	2,034	1,600
Number of traders	211	50
Total number of people	2,245	1,800
Share of farmers storing (%)	91	89
Quantity of potatoes stored		
Number of bags stored by farmers	66,308	54,000
Number of bags stored by traders	30,368	19,000
Number of bags stored by cold storage owner	326	0
Total number of bags stored	97,003	93,000
Share of bags stored by farmers (%)	68	58

Table 5: Evolution in storage behavior over the last decade

	Simple average		Weighed average*	
	% of answers		% of answers	
	1999	2009	1999	2009
Use of potato				
Seed potatoes (%)	67	52	70	53
Table varieties for sale on market (%)	33	47	30	46
Processing varieties (%)	0	0	0	0
Ownership of potatoes in cold storage				
Owned by farmers (%)	89	73	90	74
Owned by traders (%)	9	19	8	16
Owned by cold storage owners (%)	2	9	2	11

* : weighed by size of the cold storage; averages might differ with previous Table because of recall issues and lower number of oberservations

Table 6: Services provided by cold storages

	Simple average	Weighed average*
	%	%
Cold storages that arrange farmers access to seed	7	8
Cold storages that arrange farmers access to chemicals/pesticides	8	8
Cold storages that provide agricultural extension services to farmers	4	4
Cold storages that provide advance payments before storage	5	6
Cold storages that provide advance payments after storage	79	78
If yes, number of users that cold storages give advances to	25	29
If yes, advance given per bag (%/bag)	50	50
% of bags that credit was given for (using bags as collateral)	29	32
If yes, to provide credit, do you have linkage with Bank?	83	84
Cold storages contact buyers and arrange transactions for storers	56	51
If yes, number of users put in contact with buyers	40	40
% of cold storages that charge commission for contacts with buyers	7	8
Cold storages provide grading and sorting services	50	52
Cold storages provide transport services from farm to cold storage	5	5
Cold storages provide transport services from cold storage to buyer	11	18

* : weighed by size of the cold storage

Table 7: Price determinants

		Short model		Long model	
Dependent variable = Rs/kg*		Coefficient	t-value	Coefficient	t-value
Transaction variables					
Timing of sales					
- Fresh from field without drying (default)					
- Without storage after drying	yes=1	-0.157	-0.470	-0.130	-0.380
- After traditional storage	yes=1	3.635	**5.310**	3.491	**5.470**
- In/after cold storage	yes=1	6.246	**7.780**	6.065	**6.870**
Seed potatoes	yes=1	-0.039	-0.720	-0.033	-0.720
Sold to broker in village	yes=1	-0.408	-1.600	-0.448	-1.720
Quantity sold	log()	0.190	**2.680**	0.191	**2.560**
Red potato	yes=1	0.057	0.290	-0.007	-0.040
Sold to trader at cold storage	yes=1	0.657	0.940	0.950	1.030
Sold at cold storage	yes=1	1.092	1.570	0.960	1.360
% paid cash and immediately	%	0.007	0.840	0.007	0.830
Socio-economic variables					
Age of head of household	years			0.076	0.960
Age squared of head of household	years			-0.001	-1.030
Household size	number			-0.097	-0.310
Share of children in household	share			-0.381	-0.380
Share of elders in household	share			1.281	0.650
Head of household is illiterate	yes=1			0.217	0.890
Head of household has off-farm income	yes=1			-0.123	-0.410
Area of land owned	Log()			0.011	0.080
Intercept		4.596	**4.100**	2.989	1.240
Number of obs		269		256	
F()		638		.	
Prob> F		0		.	
R-squared		0.87		0.86	
Root MSE		1.59		1.61	

* standard errors estimated after accounting for within cluster(village) correlations

district dummy included but not reported

Table 8: Determinants of sales transaction after cold storage

		Without interaction						With interaction			
		Short probit		Long probit		instrumented probit		Short probit		Long probit	
		Coeff	z-value	Coeff	z-value	Coeff	z-value	Coeff	z-value	Coeff	z-value
Intercept*		-0.235	-0.870	0.785	0.670	0.366	0.330	1.878	**1.850**	2.481	1.530
Wealth indicators											
Area of land owned	log()	0.216	**2.800**	0.179	**1.980**	0.089	0.880	-0.319	-1.420	-0.426	-1.610
Marketing costs											
Quantity sold in quintals	log()	-0.126	-1.230	-0.152	-1.380	-0.001	-0.010	-0.829	**-2.300**	-0.915	**-2.430**
Travel time to nearest cold storage	hours			0.062	**1.750**	0.045	1.130			0.065	**1.890**
Travel time to nearest wholesale market	hours			-0.003	-0.770	-0.001	-0.140			-0.002	-0.530
Socio-economic variables											
Age of head of household	years			-0.036	-0.800	-0.028	-0.630			-0.017	-0.380
Age squared of head of household	years			0.000	0.720	0.000	0.560			0.000	0.380
Household size	no			0.111	0.720	0.119	0.800			0.130	0.760
Share of children in household	share			-0.453	-1.010	-0.323	-0.800			-0.298	-0.660
Share of elders in household	share			0.285	0.420	0.312	0.480			0.444	0.570
Head of household is illiterate	yes=1			-0.230	-1.320	-0.211	-1.300			-0.363	**-1.930**
Head of household has off-farm income	yes=1			0.288	**2.240**	0.280	**2.170**			0.221	**1.890**
Interaction term											
Area of land owned*quantity sold								0.1705	**2.270**	0.1863	**2.250**
Residual for quantity sold						-0.187	-1.060				
Number of observations		269		261		261		269		261	
Wald chi2		29.34		1587.69		667.06		31.72		1570.76	
Prob>Chi2		0.00		0.00		0.00		0.00		0.00	
Pseudo R2		0.04		0.06		0.06		0.06		0.08	
F-test of significance of instruments in instrumenting regression						62.06					

* standard errors estimated after accounting for within cluster(village) correlations; district dummy included but not reported

Table 9: Wastages in the potato value chain

	Harvest %	Off-season %
Wastages during marketing and storage		
Producer before storage*	2.4	2.4
Cold storage**	0.0	1.3
Producer after storage*	2.1	2.1
Rural wholesaler***#	0.7	0.7
Urban wholesaler***	0.4	0.4
Urban retailer***	2.4	2.4
Total wastage post-harvest	8.0	9.3

* wastage reported during marketing in last transaction

** from farmer surveys; cold storage only;

*** based on last transaction information

average of off-market and on-market rural wholesaler

[1] The authors acknowledge the detailed comments and suggestions of an anonymous referee. These comments improved the quality of the article considerably.
[2] Also important is that potato is mainly grown in Indo-gangetic plains in the North so that there are no multi-season flows from different zones.
[3] Cold storage is usually referred to as a refrigerated warehouse space to preserve food products. Storage conditions and length of time in storage influence the quality of the products and their consequent susceptibility to handling. By lowering the temperature during storage of food products, they can be stored for longer periods and can then be marketed during periods of the year when no production is possible. Cold storage of table and seed potatoes is usually done at a temperature of 2-4 C. However, this temperature induces the conversion of starch to sugar, leading to the sweetening of potatoes which is less desired in the market place. Customers are thus usually willing to pay a premium for 'fresh' potatoes, potatoes that have not gone through cold storage.

[4] The land allocated for the production of potatoes in Vaishali and Samastipur are 13500 ha and 12300 ha respectively in 2006-7 (Directorate of Horticulture, Government of Bihar).
[5] The sample in Samastipur was done as follows. In a *tehsil,* Gram Panchyats (GPs) were ranked from big, medium to low producing GPs (three terciles). 3 GPs was randomly selected from the big producing GPs, 1 GP was selected from the medium producing GP, and 1 GP was selected from the low producing GPs. In each selected GP, two villages was selected at random. For the GP of the lowest producing tercile, only 1 village was selected. In Vaishali, the following strategy was used. Gram Panchyats (GPs) were ranked from big, medium to low producing GPs (three terciles). 1 GP was randomly selected from the big producing GPs, 1 GP was randomly selected from the medium producing GP, and 1 GP was selected from the low producing GPs. In each selected GP, two villages were selected at random. For the GP of the lowest producing tercile, only 1 village was selected.
[6] 10 retailers were interviewed additionally on pricing specifically in May 2009.
[7] This low yield in potato is comparable to both the state and national average, but significantly lower than the yield reported by the two major producing districts in the state, Nalanda and Patna.Nalanda and Patna reported yields of 24.2and 25.5 tons per hectare respectively.
[8]Indiastat and personal communication, Bihar Horticultural Department
[9] An average cost in these two districts of 33.2 USD/ton, i.e. 75 Rs per bag of 50 kgs, would amount to 8.9 million tons of storage costs.
[10] Though Bihar was not regulated by the Cold Storage order 1964 promulgated by the Ministry of Agriculture under section 3 of the Essential Commodities Act (1955) the state had its own regulation with which it has persisted even after the Cold Storage Order was repealed by the Central Government in 1997. The Bihar State Cold Storage Business Regulation ACT 1998 mandates permissions and licenses from different government departments.
[11]Uttar Pradesh accounted for the largest share in terms of additional capacity created (2.2 million mt), number of facilities (464 cold storages), and subsidies (Rs1.4 billion). Maharashtra (216,000 mt) came second and Bihar (225,000 mt) third in additional capacity created.
[12] However, he would still be considered a big trader himself as he sells double the quantity of an average trader.
[13] Key informant interviews revealed that in many cases, services provided by the cold storage depend on the local production levels and depend by year as these services are seemingly driven by the incentive to ensure maximum capacity utilization. The general pattern seems to be that in a good production season, such incentives are not strong or disappear. However, in a bad production season, these services are offered in that increasingly competitive environment.
[14] See also Fafchamps and Hill-Vargas (2005) and Shilpi and Umali-Deininger (2008).
[15] If a farmer has only a small quantity to sell, he is less likely to bear the transactions costs to bring produce to the cold storage as these costs usually go up by unit the smaller the lot (Fafchamps and Vargas-Hill, 2006).

[16] The debate on wastage levels in India has often been linked to the debate on the benefits from FDI in retail as it is assumed that modern retail would be better in the organization of more efficient value chains.

[17] It is also important to note that transport costs of about 100 Rs/ton from producers to wholesale markets in Patna are of minor importance in the final retail price, accounting for about 1% in the final retail price. While the relatively low costs of transport is known to some, the problem that is argued to exist is that the quality of tucks and services is poor and slow, leading to high wastages (Mattoo et al., 2007). This lower importance of wastage and transport costs that we find might be due to the development of better infrastructure (cold storage and road infrastructure) but might also reflect lack of evidence in other studies on the actual situation on the ground given lack of primary data.