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Sequencing and the Success of Gradualism:
Empirical Evidence from China's Agricultural Reform

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Abstract

This paper provides evidence regarding gains to agricultural market liberalization in China. We empirically identify the different effects that incentive reforms and gradual market liberalization have on China's agricultural economy during its transition period. We find that average gains within the agricultural sector to incentive reform exceed gains to market liberalization by a factor of ten. Our method of analyzing the effects of transition policies on economic performance can be generalized to other reform paths in other transition economies.

JEL Codes:O4, P2, Q1

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At its most basic level the Big Bang versus Gradualism debate can be characterized by two questions. Should reforming nations lead with radical market liberalization policies? Or, should policy makers provide incentives for increasing productivity before central planning is dismantled and markets are unleashed?

While the debate has raged for more than 10 years, there has been little progress in understanding exactly how better incentives and liberalized markets have contributed to the success of countries in transition. Most explanations of the success of a particular reform strategy have centered on comparing growth among different reforming economies. Have countries in East Asia grown faster than those in Europe because they adopted gradual reform policies as opposed to radical liberalization policies (Roland and Verdier, 1999)? The problem with comparative studies is that they are unable to empirically isolate the factors that have positively and negatively contributed to the performance of different transitional economies. Almost no one has empirically isolated the effects of gradual market liberalization on behavior and performance throughout the reform period.

The goal of our paper is to respond to this lack of evidence. It examines the case of China's agriculture and seeks to empirically identify and differentiate the effects that the incentive reforms and market liberalization policies have on transitional economies. To meet our goal, we pursue three objectives. First, we briefly delineate the various gains that countries can expect from incentive changes (i.e., decollectivization) on one hand and market liberalization on the other. Second, we layout a framework for measuring the source of and returns to incentive reforms which have been widely studied in the past (e.g., McMillan, Whalley, and Zhu, 1989; Lin, 1992) and market liberalization initiatives. Finally, we offer initial estimates of the timing and magnitudes of returns to incentive and market reforms, which can contribute to the discussion on effective transition strategy. Although our findings do not go as far as showing why gradualism is superior to Big Bang reforms in a general sense, they do help explain why gradualism in China has been successful

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and provides a methodology for analyzing the impact of specific transition policies on economic performance.

In meeting our objectives, the study makes two main contributions to the literature. First, we provide estimates of gains to market liberalization in China. Our second contribution is our method for estimating the magnitude of returns to market reforms. We extend the empirical adjustment cost literature by developing a method of quantifying the effect of market liberalization policy shifts on economic efficiency. Our method can be generalized to other transition or developing economies that experience large scale market liberalization as part of either a transition or a structural adjustment process. To measure economic efficiency changes using an adjustment cost model, we find separate adjustment parameters for the early and late reform periods in China, which we argue coincide with pre- and post-market liberalization policy. We then exploit the difference between the two parameters to measure efficiency gains from faster adjustment, which we divide into what we call gains to flexibility and gains to responsiveness.[1]

1 Incentives, Markets, and Behavior

The literature has carefully documented the returns to increased incentives in China's early stages of reform. Decollectivization, commonly called the Household Responsibility System (HRS), made the household the residual claimant and left production decisions to those with the best information (Putterman, 1993). Although McMillan, Whalley, and Zhu (1989), Fan (1991), Lin (1992) and Huang and Rozelle (1996) use different data sets, examine different sub-sectors of the rural economy, and apply different methods, they all conclude that HRS led to sharp increases in output and greater efficiency. The HRS variable is assumed to proxy for the added incentives that decollectivization provided to producers in the early 1980s, measuring the gain from the reforms as an upward shift of the profit or production function. The increased efficiency from the early reform period is attributable to decollectivization. Implicitly, the authors assume that the incentive-based reforms were completed by 1984. In the rest of this study, we make a similar assumption: the

efficiency gains in the early reforms are caused by the new incentives that farmers received from decollectivization.[2]

In contrast, less research has focused on the nature and timing of the market liberalization reforms. In this paper, we subscribe to the argument put forth in Rozelle (1996): China's reformers made only limited progress towards dismantling the planning system for *most* of the cropping sector before 1985. This position is consistent with the papers of Terry Sicular (1988a; 1988b; 1995), which discuss the agricultural commercial reforms, and those of Perkins (1988) and Lin (1992), which document the nature of China's early rural reform. In the early 1980s, China's leadership had little intention of letting the market play anything but a minor supplemental guidance role (Sicular, 1988b). In fact, the major changes to agricultural commerce in the early 1980s almost exclusively centered on increasing the purchase prices of crops (Sicular, 1988a; Watson, 1988). The decision to raise prices should *not* be considered as a move to liberalize markets since planners in the Ministry of Commerce made the changes administratively.

After 1985, however, market liberalization began in earnest. Changes to the procurement system, further reductions in restrictions to trading of commodities, moves to commercialize the state grain trading system, and calls for the expansion of market construction in rural and urban areas led to a surge in market-oriented activity (Sicular, 1995). For example, in 1980, there were only 241,000 private and semi-private trading enterprises registered with the State Markets Bureau; by 1990, there were more than 5.2 million (ZGSYNJ, 1992).

Even after the start of market liberalization in 1985, however, the process was still start and stop (Sicular, 1995). For example, in the case of fertilizer, Ye and Rozelle (1994) show that after an early attempt at market liberalization in 1986 and 1987, perceived instability in the rural economy in 1988 led to sharp retrenchments. Agricultural officials only took controls back off fertilizer marketing and began encouraging private trade in the early 1990s. Lin, Cai, and Li (1996) argue that leaders were mainly afraid of the disruption that would occur if the institutions through which leaders controlled the main goods in the food economy were eliminated without the institutions in

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place that work to support more efficient market exchange.

Hence, in this paper, we make the assumption, that we believe is entirely consistent with the mainstream literature, that there have been two distinct policy phases in China's agricultural reforms. The early reforms (1978-84) were dominated by decollectivization and the rise in incentives for farmers. The later reforms (1985-95), in contrast, have focused on the gradual attempt by leaders to liberalize the economy and develop market institutions. The move to liberalize markets came during a time when most analysts assume that the most important incentive reforms had been completed in 1984. [3]

1.1 The record of market liberalization

Marketing and pricing reforms have led to measurable improvements in markets over the late reform era. By the mid-1990s, most food commodities were marketed by farmers at market-determined prices (Sicular, 1995). Statistical analysis indicates that integration of domestic grain markets rose and markets became more competitive and efficient (Rozelle et al., 2000). The rise of a private trading class resulted in an increase of China's grain procurement through non-official channels. The literature does not claim markets were perfect by 1995; problems remained. However, no visitor who visited rural China in the mid-1980s and then returned in the mid-1990s could miss the increase in market activity.

Few authors, however, have attempted to quantify the gains from market liberalization. Part of the problem may be the period of analyses, the inability of the research approaches to separate efficiency gains of market reform from overall gains in the reforming economy, and the breadth of the studies. Wen (1993) found total factor productivity (TFP) growth had stopped in the post-1985 period, a trend he blames on the failure of the second stage of reform. There are two shortcomings of Wen's conclusions. First, it could be that his analysis ends in 1990, a period that might be too early to have allowed the liberalization reforms to take effect. Second, he is only examining the net change in TFP and does not account for other factors that could be affecting productivity. Holding the effect of technology constant and using data through 1995, Huang et al. (2000) find that TFP

growth restarts in the 1990s, a finding that they claim could be linked to increased liberalization of the economy. Like Wen, however, they do not explicitly examine the improvements in efficiency that are associated with market development. Fan (1999) decomposes efficiency gains of Jiangsu provincial rice producers in the late reform era, and finds that there have been only limited gains in allocative efficiency after 1984. Unfortunately, Fan's study is limited to only one crop in one province, which limits the generalization of his study.

If one were to take the findings of this small literature seriously, then it would appear as if there is at most only a relatively small measured gain from market reforms in China. We believe there are three possible explanations for the previous findings. First, if market liberalization actually contributes little to growth, or does not lead to increases in output or incomes, economies that lead reform with market liberalization would not experience significant gains. Second, China's agricultural market liberalization may have proceeded so slowly that market liberalization has yet to significantly affect output. Third, it might be that the methods previously used to measure the return to markets have not fully captured the effect of market liberalization. In fact, almost all of the previous literature on this subject has tried to capture the effect of market liberalization by examining the residual growth of output after other sources of growth have been accounted for.

2 Returns to Markets: Increased Flexibility and Responsiveness

Absent or poorly functioning markets impose two constraints on economic producers. First, when markets are not well-developed, or when policies or institutional constraints raise transaction costs and limit market-based exchange, producers lack the *flexibility* to change the allocation of their productive assets and choice of enterprises. Second, as prices and other factors in the economy change, producers are less *responsive* when shifting their variable inputs. This section will explain the effects of market liberalization on flexibility and responsiveness in more detail.

To more precisely understand what is meant by flexibility, we suppose there are two aggre-

gate agricultural production functions, one in a pre-liberalization period (F_A) and one in a post-liberalization period (F_B). A profit-maximizing farmer who in year $t - 1$ faces an output price p_{t-1} chooses to produce an amount Q_A which is at a certain point on F_A, using a quantity of some quasi-fixed input X_{A1}. [4] In year t, the price increases to p_t. A farmer who is unconstrained would move to the point of optimal production by increasing the use of the input to X_{A2}.

However, if there are frictions in the economy, the producer will not be able to completely adjust the quantity of the quasi-fixed input, X, in response to the price change within one year. Instead, the producer is only able to increase the quasi-fixed input to X_{AP} in year t, a point between X_{A1} and X_{A2}. The lost profit from productin at X_{AP} rather than X_{A2} is a measure of the inefficiency due to inflexibility.

Market liberalization can reduce the amount of inefficiency as follows. Although the producer, producing on the new production frontier, F_B, is not able to adjust perfectly, market liberalization policies have facilitated exchange. This time in response to the price change from p_{t-1} to p_t, the producer can increase the use of the quasi-fixed input from X_{B1} to X_{BP}, which is a further than the one the producer made on F_A for X_{A1} to X_{AP}. The more rapid adjustment in the post-liberalization era can most easily be illustrated by comparing the number of years that it takes to fully adjust from the original production amount to the point of long-run optimality. For example, if in a pre-liberalization era it took 4 years, in the post-liberalization era it would take two years if the expansion of markets made producers more flexible.

There is reason to believe that China's producers have begun operating in more flexible environments in the late reform period, especially with regards to their choices of sown area and labor. In the late reform period, as quotas have fallen (Wang, 2000) and labor markets developed (Parish, Zhe, and Li, 1995), the scope for rural household decision making has expanded greatly. In particular, the rise of rural industry and increased opportunities to work off the farm in areas near the farmer's home village has conceivably had a large effect on the flexibility of labor use.

The lack of well-functioning markets may also limit the *responsiveness* of farmer supply and

derived demand decisions. According to one of Marshall's fundamental principles of demand, the more variable factors of production there are, the more responsive producer choices are to changes in price and other fixed factors (Marshall, 1890). If newly emerging markets allow farmers to choose more of their inputs, the increased scope for substitution among inputs will make farmers at least as responsive, *ceteris paribus*. In terms of liberalization, we would expect that if new markets emerged and facilitated exchange, producers could respond more rapidly. Empricially, this would show up as more elastic response parameters. For example, own price elasticities would become larger in absolute value terms.

While we are trying to isolate the behavioral effects of the incentive reforms from those of market liberalization, in reality it is likely the two are quite related. For example, Lin (1991) and Huang and Rozelle (1996) have shown that China's agricultural sector has experienced both positive and negative interactions between market improvements and improved incentives.[5] Since we are trying to identify the effect of increased market liberalization, quantitative measures of the liberalization should not be affected if the incentive reforms were already implemented and fully effective by the mid-1980s. However, increased responsiveness is conditional on having good incentives, so when one considers how policies should be sequenced in this case, the true returns to liberalization policies will be overstated if all of the efficiency gains in the late reform period are attributed to them.

3   Measuring Behavioral Effects of Market Liberalization

As discussed above, the increase in the speed by which quasi-fixed factors adjust corresponds to increased *flexibility*. To estimate the adjustment speed of quasi-fixed factors while considering the main sources of production growth, a theoretical and empirical framework that explicitly accounts for the elements that facilitate or constrain producers from adjusting inputs and outputs to their optimal levels in response to exogenous shocks is needed. Such approaches exist, including the agricultural treadmill (Cochrane, 1965), fixed asset theory (Johnson, 1956; Hathaway, 1963), and

adjustment cost models (Lucas, 1967; Johnson and Quance, 1972).

The adjustment cost approach is particularly appropriate for modeling the production behavior of China's farmers in a reform economy because it allows us to measure the rate of adjustment of resources in response to exogenous changes. Factors that are slow to adjust are called quasi-fixed inputs and are endogenous variables; their levels and rates of change are in part chosen by the producer in response to changes in exogenous factors. Quasi-fixed inputs affect production in both the short- and long-run. A theoretical framework is described in Appendix A as well as in Warjiyo (1991).

3.1 Empirical model

To measure quasi-fixed factor flexibility, we follow Epstein (1981) who specifies the dynamic value function (equation (A.1) in Appendix A) as a normalized quadratic value function, $V(\cdot)$:

$$
V(p, w, q, K, Z) = a_0 + \begin{bmatrix} a_1 & a_2 & a_3 & a_4 \end{bmatrix} \begin{bmatrix} p & w & q & K \end{bmatrix}' +
$$

$$
\frac{1}{2} \begin{bmatrix} p & w & q & K \end{bmatrix} \begin{bmatrix} A & F & G' & H' \\ F & B & L' & N' \\ G & L & C & (R^{-1})' \\ H & N & R^{-1} & D \end{bmatrix} \begin{bmatrix} p & w & q & K \end{bmatrix}' +
$$

$$
\begin{bmatrix} a_5 & p & w & q & K \end{bmatrix} \begin{bmatrix} X_0 & X_1 & X_2 & X_3 & X_4 \end{bmatrix} Z \tag{3.1}
$$

where p, w, and q are prices of output, variable inputs, and quasi-fixed inputs, respectively; K and Z are levels of quasi-fixed inputs and exogenously determined control variables; and a_0, ..., a_5, A, F, G, H, B, L, C, R, D, X_0, ..., X_4 are parameter matrices with appropriate dimensions. The empirical formulation of the complete system of input demand and output supply equations, corresponding to equations (A.3) to (A.5) in Appendix A, has the form:

$$
\Delta K_t = \Theta_{12} + (rU + R)K_{t-1} + rRGp_{t-1} + rRLw_t + rRCq_t + T_{12}Z_t + e_{12,t} \tag{3.2}
$$

$$
L_t = \Theta_3 - rFp_{t-1} - rBw_t - rL'q_t - N'K_t^* - T_3Z_t + e_{3,t} \tag{3.3}
$$

$$Y_{12,t} = \Theta_{45} + rAp_{t-1} + rF'w_t + rG'q_t + H'K_t^* + T_{45}Z_t + e_{45,t} \tag{3.4}$$

$$\begin{aligned}
Y_{3,t} = {} & \Theta_6 + ra_4 K_t^* - \frac{1}{2}rp'_{t-1}Ap_{t-1} - \frac{1}{2}rw'_t Bw_t - \frac{1}{2}rq'_t Cq_t \\
& -rp'_{t-1}F'w_t - rp'_{t-1}G'q_t - rw'_t L'q_t + 0.5rK'_{t-1}Dk_{t-1} \\
& -\Delta K_t DK_{t-1} + rT_{60}Z_t + Z_t T_{61}K_t^* + e_{6,t} \tag{3.5}
\end{aligned}$$

where $\Theta_{12} = rRa_3$, $\Theta_3 = -ra_2$, $\Theta_{45} = ra_1$, $\Theta_6 = ra_0$, $K^* = rK(t-1) - \Delta K(t)$, $T_{12} = rR^{-1}X_3$, $T_3 = -rX_2$, $T_{45} = rX_1$, $T_{60} = a_5 X_4$, and U is an identity matrix. Our empirical model actually consists of two quasi-fixed inputs (represented by equation (3.2)), one variable input (equation (3.3)), and three outputs (equations (3.4)-(3.5)). We consider sown area and labor to be quasi-fixed inputs, so K in equation (3.2) represents an equation that explains the change in sown area and an equation that explains the change in labor. ΔK represents the change in quasi-fixed factor level between period t and period $t-1$. Fertilizer is the variable input, represented by L in equation (3.3).[6] The three output equations explain production of wheat, maize, and cash crops; Y_{12} is a two-element output vector for wheat and maize, and Y_3 represents cash crop output. Prices for wheat and maize, the variable input (fertilizer), and the two quasi-fixed inputs (labor and sown area) are normalized by the cash crop price to satisfy homogeneity. The Z vector is made up of three shift variables: national research stock, irrigation capacity, and a variable reflecting the effect of institutional incentive reform.[7] Provincial dummy variables account for fixed, province-specific effects. Conditions for consistent aggregation requires $V_{KK} = D = 0$ (Epstein and Denny, 1983), which is imposed in estimation.

As sown area and labor are considered to be quasi-fixed inputs, it is costly to adjust them to the optimal level. The R matrix in equations (3.1) and (3.2) is known as the adjustment matrix, and the coefficients on the diagonals of R can be called adjustment cost parameters. The parameters are estimates of the average, one-period proportional adjustment of a quasi-fixed factor to its long-run optimal level that is made in response to a change in an exogenous variable. The partial adjustment cost model, then, gives us explicit measures of the flexibility of quasi-fixed factors. The diagonals

of the R matrix, in some sense, are exactly what we are interested in: a measure of how well markets allow factors to adjust. Appropriately, some researchers call these estimated parameters flexible acceleration coefficients (Warjiyo, 1991).

3.2   Measuring Flexibility and Responsiveness

To measure the *change of flexibility*, we interact a dummy variable (that is zero for the early reform period, 1975-84, and one for the late reform period, 1985-95) with all of the variables in equation (3.1) and (3.2) associated with the adjustment parameters (that we will call R_{11} and R_{22}).[8] The parameters associated with the interaction term (denoted R_{11D} and R_{22D}) measure how much more or less flexible quasi-fixed factors become in the market liberalization period.

The adjustment cost model generates two types of elasticities that describe the relationship between the choice variables (i.e., variable and quasi-fixed inputs and outputs) and exogenous factors. The short-run elasticities measure the one period response of choice variables to shifts in prices and policy variables, including *direct and indirect changes* of variable inputs and outputs. *Indirect changes* occur through the partial quasi-fixed factor response of the producer. As quasi-fixed factors do not fully adjust in one period, the indirect change in the variable input or output amount reflects the speed of adjustment of quasi-fixed inputs. Therefore, the slower the adjustment process, the smaller the elasticities are in absolute value. Long-run elasticities, on the other hand, account for the full adjustment of quasi-fixed inputs, and measure both the *direct* and the optimal, complete *indirect* response of producers to price changes. The indirect portion of the elasticity accounts for the *full* shift in quasi-fixed inputs to their optimal amounts after the price change occurs. Warjiyo (1991, p. 65) includes detailed calculations for deriving the short- and long-run elasticities from the estimated parameter matrices in equations (3.2) to (3.5). We will take advantage of the differences between these two relationships, since one measure, the long-run elasticity, lets us measure the full response to a change in price. The other measure, the short-run elasticity, captures the extent of the inefficiency of the incomplete indirect response, since *ceteris paribus*, the smaller the response, the greater the inefficiency.

Since our model includes quasi-fixed factors and variable inputs, we can estimate responsiveness by using the parameters of the model to calculate measures such as input price elasticities. Ideally, we should measure the *change* in responsiveness between the early and late periods by separately estimating equations (3.2) to (3.5) for the early and for late periods, and comparing the results. In the period after market liberalization has begun, we would expect to find higher absolute values of the elasticities. Such a finding would intuitively show that producers were becoming more responsive as markets emerged. And a more responsive producer will see higher profits than a less responsive one.

Unfortunately, the size of the data set makes the estimation of two separate models impossible.[9] As a compromise, we re-estimate our original model for the full period with a more "flexible specification" by interacting the parameters associated with the own-price responses with the sub-period dummy variable.[10] We use the parameters from this estimation to generate short-run elasticities for early and late periods to examine how the responsiveness of China's producers changes as markets emerge.

4 Efficiency Gains from Increased Responsiveness and Flexibility

4.1 Creating the measure of increased efficiency due to market liberalization

The first step in arriving at an estimate of the gains to market liberalization is to calculate the inefficiency *in any given economy* that arises from imperfect adjustment. The difference in lost profits between the full adjustment and the partial adjustment is a measure of the inefficiency due to partial adjustment, and is defined as:

$$\Omega_t = \Delta\Pi_{t,full} - \Delta\Pi_{t,partial} \tag{4.6}$$

where $\Delta\Pi_{t,full}$ is the amount of additional profits that the producer would earn from a price increase (from p_{t-1} to p_t) if there were no adjustment costs or frictions from year $t-1$ to t (or if full

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adjustment occurs in one year), compared to the amount that profits would change if producers did not adjust at all. $\Delta\Pi_{t,partial}$ is the additional profits realized if the producer only partially adjusts, again compared with the case where producers do not adjust. [11]

To create a measure of the *change* in inefficiency between two periods, we first label the early, incentive reform period (before market liberalization) when producers are expected to be less responsive as "slow" and the late, market liberalization period when partial adjustment is expected to be faster as "fast". Then, we can use equation (4.6) to calculate the inefficiency for the late reform period as:

$$\Omega_{t,fast} = \Delta\Pi_{t,full,fast} - \Delta\Pi_{t,partial,fast} \tag{4.7}$$

We do the same calculation using the parameters from the incentive reform period:

$$\Omega_{t,slow} = \Delta\Pi_{t,full,slow} - \Delta\Pi_{t,partial,slow} \tag{4.8}$$

If market liberalization policies lead to faster adjustment when prices change in the late reform period, the overall gain in year t during this period, G_t, to increased flexibility and responsiveness can be calculated by subtracting equation (4.7) from equation (4.8):

$$G_t = \Omega_{t,slow} - \Omega_{t,fast} \tag{4.9}$$

To compute G, we need to start with a measure of profits. Since almost no land is rented in China and almost no labor is hired for farming, we define profits as returns to land and labor, and can write it as:

$$\Pi_t = \sum_i P_{it} Q_{it} \tag{4.10}$$

where P represents all output and variable input prices, Q represents output and variable input quantities, and i indexes them (i=wheat, maize, cash crop, and fertilizer). Variable inputs (in our

case, fertilizer) are taken to be negative quantities. Following this notation, the change in profits, $\Delta\Pi_t$, from year $t-1$, Π_{t-1}, to year t, Π_t, can be expressed as:

$$\Delta\Pi_t = \Pi_t - \Pi_{t-1} = \sum_i (P_{it}\Delta Q_{it} + Q_{it-1}\Delta Q_{it}) \tag{4.11}$$

where ΔQ_{it} is the change in output or input quantities between $t-1$ and t, and ΔP_{it} is the corresponding price change. The term ΔQ_{it} is calculated using equation (4.12):

$$\Delta Q_{it} = Q_{it} \sum_j \frac{\Delta\rho_{jt}}{\rho_{jt}} \, \varepsilon_{jt} \tag{4.12}$$

where ρ represents all prices and government policy variables, j indexes them (j=wheat, maize, cash crop, and fertilizer prices; research and irrigation stocks), and ε represents all elasticities.

Equation (4.12) can be calculated using either the long- or short-run elasticities. When it is calculated with long-run elasticities, the quantity responses reflect that quasi-fixed factors *fully* adjust and the producer is at a point of optimal profits. When it is calculated with short-run elasticities, quasi-fixed factors only *partially* adjust, the indirect responses are ignored, and the producer is *not* at a point that maximizes profits.

To get the profit maximizing output responses to a given change in a price or exogenous variable, we can insert estimates of long-run elasticities into equation (4.12), and then find the predicted change in profits by inserting the predicted ΔQ_{jt} into equation (4.11). In fact, if our change in an exogenous variable is a change in price from year $t-1$ to t (which we can call ΔP_{jt}), then our resulting change of profits is $\Delta\Pi_{full}$, and is exactly what we need to begin calculating inefficiency (Ω and G). If we are using estimates of long run elasticities from the pre-market liberalization era and actual changes in the exogenous variables from the second period to calculate ΔQ_{jt}, we can use this measure to calculate $\Delta\Pi_{full,slow}$. If we use short-run elasticity estimates for the pre-market liberalization period to calculate ΔQ_{jt}, then the corresponding measure $\Delta\Pi_{partial,slow}$ can be calculated. reflects that quasi-fixed factors do not fully adjust, as short run elasticities from the early reform period are used. The difference between $\Delta\Pi_{full,slow}$ and $\Delta\Pi_{partial,slow}$ with is our measure of inefficiency (Ω_{slow}) that is due to market imperfections. In essence, Ω_{slow} is a measure of the

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conceptual experiment: how much would profits fall if flexibility and responsiveness in the market liberalization period had not changed from the earlier incentive reform period?

To compute our measure of the change in efficiency due to market liberalization, we also need to measure the inefficiencies in the market liberalization period, Ω_{fast}. These calculations are exactly the same as for Ω_{slow}, except that we use the long and short run elasticities estimates from the second period. Once calculated, the estimates of Ω_{fast} and Ω_{slow} can be substituted into equation (4.9) to get a measure of the overall gain in efficiency in year t from market liberalization, G_t.

4.2 Decomposing the measure of the gain to efficiency from market liberalization

We actually break down the total efficiency gains, G_t, even further, into one part that arises from increased flexibility and one that is due to increased responsiveness. By substituting equations (4.7) and (4.8) into (4.9) and rearranging, we find that G_t can be written as:

$$G_t = -((\Delta\Pi_{partial,fast} - \Delta\Pi_{partial,slow}) + (\Delta\Pi_{full,fast} - \Delta\Pi_{full,slow})) \qquad (4.13)$$

As written, the two terms in equation (4.13) have intuitive interpretations that correspond to the two changes to efficiency caused by market liberalization. The first term is the loss of profits that would have resulted had the speed of adjustment been the same in the second period as the first. This is just a measure of the change in efficiency due to flexibility (F_t). The second term is just the profit lost if market liberalization had not led to larger long run elasticities, which is just responsiveness (R_t). Hence, we can write G_t as $G_t = F_t + R_t$.

4.3 Measuring the gain to better incentives

To meet our goal of assessing the relative effects of market liberalization, we also need measures of the gains to the incentive reforms. We create such a measure by using our estimated empirical model to simulate profits in the early reform period (1978-84), with and without the shift

attributable to the incentive reforms. Since the decollectivization variable enters equations (3.1) to (3.5) linearly, the coefficients on the HRS variables can be interpreted as the shifts in production behavior that can be attributed to HRS as the incentive reforms are implemented. The difference between the simulated profits with (Π_t^*) and without ($\Pi_t^{'*}$) the incentive reforms measures the gains in economic efficiency.[12] Normalizing by Π_t^*, we have a measure of the gain to incentive reforms, I_t, which is the proportion of increased profits due to the reforms:

$$I_t = \frac{\Pi_t^* - \Pi_t^{'*}}{\Pi_t^*} \tag{4.14}$$

5 Data

Provincial-level cross-section, time-series data for 1975 to 1995 are used in the analysis.[13] Output for wheat, maize, and other grains, and cash crops (cotton, sugar cane, peanuts, and rapeseed) are measured in kilograms and after 1980 are from published statistical compendia (ZGTJNJ, 1980-1993; ZGNYNJ, 1980-1996). Prior to 1980 data for these variables come from provincial yearbooks.[14] Data on total sown area in each province are from the same sources. Cash crop output is an aggregated variable; output values for each individual crop are summed, then divided by a Stone price index.

Prices for grain, cash crops, and fertilizer are obtained from China's national Cost of Production Survey (CCPS).[15] This information comes from a data-collection program run by the State Price Bureau since the mid-1970s (SPB, 1988-96). Based on annual household surveys conducted by county level Price Bureau personnel, detailed information is available by crop and by variety for over 50 variables, including revenue, expenditure (in value terms) and quantity data.[16] Prices are generated by dividing total revenues or expenditures by the quantity. This procedure gives us an average price or a unit value. While we usually assume that producers respond only to the marginal price, Lin (1991) theoretically shows that if the producer's marketing quota is output-dependent, the producer's production decisions depend on both the quota and market price. The best specification would include both prices, but unfortunately these data are unavailable. By constructing

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and using average prices, we implicitly assume that producers are responding to an average price, constructed of quantity-weighted state and market (or "negotiated") prices. While it is conceivable that this assumption could affect the results, in practice we believe that there is little problem. Using a similar data set, Wang (2000) shows that there is little econometric difference between the unit value and the marginal price. The correlation coefficient between the marginal price and the unit value exceeds 0.95.

Other price variables are also computed using the data from the CCPS. The price for land is calculated as net return to cultivated land (total revenue per unit of cultivated land for each commodity less per land unit expenditures on labor, fertilizer, and other variable inputs). The wage is derived from per capita labor income in rural areas.

The irrigation and research stock variables were created from public expenditure data using formulae detailed in Appendix C. The formulae account for depreciation and lagged effects. Irrigation expenditures are from each province, and are documented in a statistical compendium published by the Ministry of Water Resources and Electrical Power (MWREP, 1988-1996). They include all sources of investment in water control that pass through the fiscal system to regional water conservancy bureaus. National grain research expenditures are assumed to have the same effect on production in each province, implicitly implying that breakthroughs spillover into all provinces. Cash crop research expenditure data come from the State Science and Technology Commission.

The incentive reform variable measures the cumulative proportion of households in China each year that had implemented decollectivization policies. Data for the variable come from Lin (1992).

6 Econometric Results

6.1 Grain and Cash Crop Production in North China's Reforming Economy

We use a non-linear, three stage least squares estimator (Gallant, 1977) to estimate the relationship among the two quasi-fixed inputs (equation 3.2), three outputs (equations 3.4 and 3.5), and

one variable input (equation 3.3). The estimator accounts for contemporaneously correlated error terms. The 6 equation system for North China contains 46 exogenous variables and 135 parameters.

The entire set of estimated coefficients for equations (3.2) to (3.5) are reported in Appendix B. Many of the coefficients have high t-ratios; the signs and magnitudes of most coefficients are as expected. Our important results also appear to be robust to the choice of estimator. In particular, the flexible accelerator parameters, R_{11} and R_{22} are negative and significant (Table 1). Because the model is written in terms of first differences, the eigenvalues of the adjustment matrix R provide a check on the stability of the adjustment process of land and labor. Since the absolute values of the estimated eigenvalues for R are less than unity, the quasi-fixed demand system is stable.

The properties of the value functions also are mostly satisfied. The estimated value function is non-declining in p (wheat and maize), K_1 (sown area), and Z (agricultural research and irrigation investment), and is non-increasing in w (wage) and q (the price of labor and value of land). The only violation of monotonicity is found in K_2 (labor), a result commonly found in other studies (see survey by Warjiyo, 1991). When considering parameters significant at the 10 percent level, convexity is satisfied for the sets of equations; the own-price response matrices (A, B, and C) are all positive semi-definite.

Estimates of government policy variables also have the expected impacts on agricultural production. For example, positive signs on the IRR_4 and IRR_{60} parameters (Appendix B) indicate that irrigation investment boosts wheat and cash crop production. The estimated coefficient for maize, IRR_5, is negative and insignificant, which reflects the fact that Chinese farmers tend to grow maize on more marginal, hilly land. Irrigation also seems to save labor (IRR_2). Agricultural research boosts both wheat and maize output (RES_4 and RES_5), but has an insignificant effect on cash crop production (RES_{60}). This result reflects the observation of Fan and Pardey (1992) that the agricultural research system has been focused on grain. The positive and significant coefficients on the variable associated with the effect of research on labor (RES_2) indicates

that agricultural research has intensified labor use. The signs of the coefficients associated with the variables measuring incentive reform (HRS), imply that it had a positive impact on the production of all crops except for maize in North China, which coincides with the result found by other studies (e.g. McMillan, Whalley, and Zhu, 1989).[17]

6.2 Increasing Flexibility during China's Reforms

6.2.1 Adjustment in the Early Reform Period

The model allows us to test a series of hypotheses related to the initial assumption that changes in the use of labor and land require significant adjustment costs, and the hypothesis that the speed of adjustment increases after the HRS reform is complete.[18] The results of two sets of hypothesis tests are reported in Table 2. Since we have interacted the variables associated with the speed of adjustment parameters with a period dummy variable, the interpretations of R_{11} and R_{22} pertain to the early reform period.

The high test statistics in the tests of quasi-fixity of sown area by itself (row 1) and labor by itself (row 2), and the joint test of the two quasi-fixed inputs (row 3), highlight the importance of accounting for dynamic adjustment costs in the analysis of China's agricultural crop area and farm labor decisions during the incentive reform period. Tests of quasi-fixity for adjustment coefficients in the market liberalization period indicate that sown area and labor do not fully adjust in one year (rows 4 and 5). Given that there are adjustment costs, the next test in this set (row 6) indicates that the adjustment paths are not independent. In other words, if an exogenous shock occurs, making the previous allocations of sown area and labor less than optimal, the movement of sown area towards its new, long-run equilibrium point (i.e., the profit-maximization point) is affected by the adjustment process of labor (and *vice versa*).

To estimate the time of adjustment in the early reform period, we invert the R matrix, and find that in the early reform period, land adjusts in about 6 years, and labor in 3 years. These figures are consistent with the findings of Huang, Rosegrant, and Rozelle (1995), who estimate adjustment times of 5 years for land and 4 years for labor for the agricultural economy as a whole

during the entire post-1978 era. Hence, our results can be interpreted as indicating that frictions in the economy kept producers from fully adjusting their labor or sown area during the early reform period.

Even though sown area and labor do not adjust instantaneously, according to this metric, during the incentive reform period China's rural economy is not particularly rigid in a comparative sense. Natural-, behavioral-, and policy-created barriers exist in every agricultural economy. When these results are compared with results of similar adjustment cost analyses in other countries, one might conclude that China's crop sector was adjusting rather quickly. With the exception of Vasavada and Chambers (1986)– who found sown area for certain crops in the United States adjusts to a new optimum after two years– analysts estimate that sown area in Canada can take up to 15 years to equilibrate after exogenous shocks (Warjiyo, 1991); whereas labor requires 6 to 19 years (Warjiyo, 1991; Luh and Stefanou, 1991; Vasavada and Chambers, 1986). Despite the existence of policy-created barriers in China, adjustment may occur faster than in North America because the relatively labor-intensive farming systems and more responsive, small scale rural-based industrial sector ultimately make resource reallocation among sectors less costly. Apparently, even though formal markets are not complete, informal institutional arrangements may have allowed China's farmers to engage in exchange even in the early reform period.

6.2.2   Changes in Flexibility in the Late Reform Period

So have the market liberalization reforms increased the flexibility of China's agriculture? The negative and statistically significant coefficients on the interaction terms in Table 1 (R_{11D} and R_{22D}) demonstrate that quasi-fixed factors have begun to adjust even faster in the late reform period. The negative coefficients are to be interpreted as the degree by which flexibility increases in the market liberalization period.

The results demonstrate that flexibility increased significantly in the second period, although the pace of improvements increased rapidly to labor and more modestly to sown area. The flexible acceleration parameter for labor is -0.60 ($-0.35 - 0.25$). In terms of the time to fully adjust,

the speed of adjustment increases to 1 2/3 years after market reform began. If faster adjustment of labor by producers are made possible by better markets and less restrictions on producers, the liberalization reforms have increased efficiency in China's late reform economy. The findings that labor markets have begun to operate more effectively are consistent with the results of Knight and Song (1999).

The speed of adjustment of sown area, however, rises only marginally; it adjusts in 5 years rather than in 6 during the late reform period. The flexible adjustment parameter was -0.20 $(-0.16 - 0.04)$.[19] This result is consistent with the observation that prior to 1995, deregulation and liberalization of land policy has occurred more slowly than the relaxation of labor restrictions. Given the leadership commitment to gradualism, the result is not surprising. In terms of the time to fully adjust, the speed of adjustment becomes faster for both quasi-fixed factors. During the late reform period, labor adjusts in 1 2/3 years, while land adjusts in 5 years. In the last section of the paper, we examine the magnitude of these efficiency gains.

6.2.3 Changes in Responsiveness in the Late Reform Period

We have also produced evidence that responsiveness increased during the market liberalization period. To show the increase, we calculate short-run elasticities using parameter estimates from a model that allows own-price responses to change across periods. We do so by adding an interaction term created by multiplying the period dummy by each price. The interaction terms are all significant at the 10 percent level, which indicates that own-price responses change after market liberalization begins (for the full set of parameter estimates, see de Brauw et al., 2000). Table 3 summarizes the changes in responsiveness of quasi-fixed and variable inputs to own prices (own-price elasticity changes based on estimating changes in parameters across periods). Among all inputs, responsiveness of labor appears to rise most significantly (row 2). The elasticity of sown area does not change (row 1). In this sense, the responsiveness of labor relative to that of sown area mirrors the results for flexibility and relative small changes.

Somewhat unexpectedly, the own-price elasticity for fertilizer seems to show less price re-

sponsiveness in the second period (row 3). To explain the somewhat counter-intuitive results for fertilizer, we return to our earlier discussion of the start and stop nature of the fertilizer reforms. The liberalization of fertilizer markets did not become permanent until the 1990s, so it is possible that we should not expect to see producers change their behavior with respect to fertilizer during the mid-1980s; following this logic, increased responsiveness should not begin until the early 1990s. To test whether the fertilizer own-price elasticity becomes more responsive for the second half of the late reform period, we re-estimate the model with own-price responses again, this time interacting them with a dummy variable that is 0 for all years before 1990, and 1 thereafter. Our results with the new model find increased responsiveness in the use of fertilizer in the second half of the late reform period (row 5). This set of own-price fertilizer elasticities indicates that fertilizer does eventually become more own-price responsive (-0.229 before 1990, -0.446 thereafter).

6.3 Efficiency Gains from Increased Responsiveness and Flexibility

Our efficiency measurements for comparing returns to the incentive reforms in the early reform period with the returns to market liberalization in the late reform period are presented in Table 4. Gains to the incentive reforms are only calculated for the years 1978 to 1984 in order to highlight the fact that HRS, which was completed in 1984, significantly boosted farm incomes in the early reform era. In fact, the gains in profits from HRS continue indefinitely, since there would almost certainly have been a fall in income after 1985 if the HRS policy were reversed and the incentives that HRS provided to farmers were weakened.

Our results clearly show the large contribution of HRS to farm incomes during the early reform period. The gains from the incentive reform increase throughout the period, rising as HRS spread through the economy. In 1984, the peak year, farm profits rise by more than 7 percent, holding other factors constant. While this percentage is less than the additions to production output and production growth measured by McMillan, Whalley, and Zhu (1989) and Lin (1992), they are not inconsistent. The increases found in this paper are net of increases in prices and other shifts due to technology and infrastructure improvements. Moreover, since farm income during the reform

period was such a large part of total rural household income, this increase represents a significant rise in the wealth of rural areas. Additionally, this is an average figure; some regions gained more and others gained less. Aggregating the total increase in profits from just farm production across more than 200 million rural households represents an immense gain of wealth.

The results of this exercise show that on a year to year basis, the overall gains from market liberalization have increased efficiency between 0.12 and 1.73 percent (Table 4, column 2). G_t is lower when prices declined, and higher in years when the price level increased sharply. At the extremes, in 1990, when the real price of wheat declined by 4 percent and the real maize price declined by 8 percent, G_t is the smallest. On the other hand, as real prices rose steadily through the mid-1990s, G_t reached its highest annual growth in 1994.

Relative to the gains in the incentive reforms, the gains from market liberalization not only start later, by policy choice, but they are also smaller (Table 4, column 2). The average annual gain to market liberalization from 1985 to 1995 is 0.73 percent, which implies it is roughly 10 times smaller than the annual rise in profits due to incentive reforms at the end of that period (7.55 percent). Even at their peak, in 1994, aggregate gains to market liberalization are less than 4 times the size of the gains to incentive reform. Figure 2 illustrates the size of the gains to incentive reform versus the size of the gains to market liberalization. The large returns to better incentives, on the left side of the illustration, overwhelm the gains in the later reform period, on the right hand side of the graph.

The findings suggest that reforming incentives had much higher returns than reforming markets in rural China. This conclusion is reinforced when considering the fact that our returns to market liberalization may be overstated since the returns are, in some sense, conditioned on the earlier reform of incentives. Although small, the gains to market liberalization may be increasing in the latter half of the liberalization period (see upward trend between 1990 and 1995 in Figure 2), which may indicate that large returns to market liberalization could still be realized.

Decomposing the returns to market liberalization, we see that most of the change has come

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from increased flexibility (Table 4, column 4). On a year to year basis, the returns to producers being more flexible to exogenous changes to prices and other factors average more than 0.50 percent per year. The gains from flexibility have also been fairly constant over time, ranging from 0.39 to 0.94 percent. Moreover, since producers became more flexible between the periods and the level of most of the exogenous variables, such as prices and the research and capital stock, rose, the returns to flexibility were never negative.

In contrast to the returns from increased flexibility, the returns to increased responsiveness are smaller and more variable (Table 4, column 3). In part the small gain from increased responsiveness is simply because the increase in elasticities, especially for sown area, is relatively small. The variability of the returns is just a function of the fact that economies experience year-to-year fluctuations in important factors, such as prices.

6.4   Comparing Market Liberalization with the Incentive Reforms

Before drawing conclusions from our findings, it is important to note that the comparison of the returns to the incentive reforms and the returns to the market liberalization reforms is complicated by several factors. First, we have a continuous measure of HRS, and know that by 1984 the policy was completely implemented. Second, by the nature of the policy, it is reasonable to assume that the policy was relatively quick to meet its goals of increasing incentives for producers to exert more effort. In other words, we interpret our measure of a 7.55 percent gain in economic efficiency by 1984 to be the result of a policy that was completely implemented and had its immediate goals mostly realized.

In contrast, we do not have a continuous measure of the market liberalization reforms. Instead, we estimate parameters that only allow us to compute the average returns to the market liberalization reforms. However, we know from our discussion of the implementation of the market liberalization reforms that even by 1995, the last year of our sample, the reforms were not completed. Moreover, there is reason to assume that the liberalization policies will be relatively slow to realize their goals. As pointed out by McMillan (1997) and others, the operation of markets

depend on the emergence of and coordination among many institutions, all of which takes time to develop.

The differences in the nature of the reforms and methods for measuring the reforms make it important to exercise caution when interpreting our comparisons. First, our measures of the incentive reforms and the market liberalization reforms may differ in part because the incentive reforms are complete and the effects immediately realized, whereas the market liberalization reforms are incomplete and the effects are only gradually being realized. Second, there is a potential difference that arises because we have a continuous measure of the incentive reforms and not for the market liberalization reforms. As a result, we can compute a return to HRS in one year, 1984, and measure the *total* gain to economic efficiency from the policy in the year of its completion. Although we can compute annual increases in profits due to the market liberalization reforms, they are created using coefficients that based on the average gain in flexibility and responsiveness of the policies that have been implemented between 1985 and 1995.

One way to control for the second source of difference between the two measures would be to ignore our information about the gradual implementation of the incentive reforms and include an early reform period dummy variable instead of the cumulative proportion of households that had adopted HRS. The estimated coefficient of this more blunt measure of the incentive reforms would only allow us to compute a measure of the average economic efficiency gains from HRS. When we do this (coefficients not reported), we find that the average gains is somewhat smaller, 5 percent, than our estimate of the cumulative gain, 7.55 percent. However, it is still much larger than the average gain for the market liberalization reforms, 0.73 percent. The difference between the 5 percent average gain from the incentive reforms and the 0.73 percent average gains from the market liberalization reforms is due to the inherent difference in returns and the extent and realization of the implementation of the market liberalization reforms.

7 Conclusions

In this paper we have developed a framework to estimate how market reforms affected producer behavior in China, and to measure the effects of market liberalization on farm returns. Building on the adjustment cost literature, we have developed a measure of the changes in efficiency that arise during periods of market liberalization. The metric can be broken down into two measures, the returns to responsiveness and the returns to flexibility.

Our results find that the behavior of producers in China has been affected significantly by the liberalization reforms, but the effects have been relatively modest. Although these findings are consistent with earlier attempts to measure the effects of market liberalization reforms by others, our results cover a larger area of China, cover a longer time period, and decompose the sources of the efficiency gains. Farmers have increased their speed of adjustment between the early and late reform period for labor and a lesser extent for sown area. Our estimates of own-price elasticities for labor and fertilizer indicate that producers are also becoming more responsive. These changes in behavior have also translated into moderate gains in the late reform period. The magnitude of the gains in efficiency from increased responsiveness and flexibility in the late reform period, however, appear to be substantially less in percentage terms (less than 1 percent per year) than that from the incentive reforms in the early reform period (up to 7 percent). However, the effect of market liberalization may be increasing slightly over time.

Based on this record, what can be said about the success or failure of China's reforms? First and unambiguously, our work is consistent with a story that gradual transition has worked–at least in the case of China's agricultural sector and at least through the second decade of reform. The incentive reforms generated large increases in output and productivity and the market liberalization reforms have not led to a decrease in either. Furthermore, the gains to market liberalization are found given that incentive reform had already occurred. Had China led reforms with market liberalization rather than incentive reform, it is unclear that market liberalization would have led to the same gains in agriculture.

Judging the effectiveness–positively or negatively–of the market liberalization reforms, however, may be premature. It is tempting to say, on the basis of our results, that the gains from market liberalization have been disappointingly small, and that the emergence of markets has only marginally increased flexibility and responsiveness and has not led to large increases in growth of the agricultural sector. A more careful interpretation of our results may lead to other conclusions. First, our paper does not attempt to measure the gains of increased resource mobility between the agricultural sector and the rest of the economy. These effects could be quite large. Moreover, even within agriculture we do not know if we are seeing changes in efficiency due to relatively small changes in markets *or* if the market reforms have largely been completed, and most of the growth potential has already been captured. If the former interpretation is correct, the outlook for future agricultural growth may be quite optimistic. It may be that continued market liberalization will eventually lead to large increases in the performance of the agricultural economy, but to date China's gradual shift to the market is just that– gradual. If continued market liberalization promises steady, or even increasing, profit growth, our paper would be consistent with calls for China's leadership to strengthen its resolve to carry through with its market reforms.

Notes

[1]However, our study also has limitations. Because we limit our study to the cropping sector, our estimates for the gains to market reform do not account for some efficiency gains that may have occurred in other sectors of the economy. For example, we do not account for gains that may have occurred because labor is more free to move off the farm. We recognize that these gains may be significant and should be studied in the future.

[2]Other institutional changes have had a number of important incentive effects associated with them, such as improved land tenure. We are ignoring them here, or claiming that the incentives for investing in land were sufficiently strong in the HRS reforms that the residual rights to farm output and the claim to the increase in land value are indistinguishable. As will be argued below, we believe the rise of markets, although affecting incentives, should not be confused with reforms that created the efficiency increasing incentives (see Lin, 1991 and Huang and Rozelle, 1996). Rather, markets allow actors that face good incentives more scope for efficiently using resources. In this respect, we interpret market liberalization more narrowly than McMillan (1997).

[3]We, of course, recognize that in reality the division was not so precise. Certainly there was some, albeit minor, relaxation of marketing restrictions prior to 1985. Furthermore, we also recognize that incentives were not perfect by 1985 and that they improved after 1985, a fact that this must be considered in the interpretation of our results.

[4]Quasi-fixed inputs can be defined as inputs that take more than one period to adjust to changes in relative prices or other exogenous factors.

[5]In both Lin (1991) and Huang and Rozelle (1996), own-price output elasticities of farm producers rise after HRS, but the total output shows a secular drop due to the demise of some centrally planned policy functions that free market agents do not take over.

[6]We also test whether fertilizer is a quasi-fixed input by specifying the model with three quasi-fixed input equations and three output equations. We found that after 1985 we could not statistically reject the hypothesis that fertilizer is a variable input, indicating that at least over some portion of the study period, fertilizer acts as a variable input.

[7]The two quasi-input equations only contain the three element vector of shift variables explained in the text. The three crop output equations also include variables that measure erosion and local environmental degradation. When explaining aggregate grain yields in China's provinces, Huang and Rozelle (1995) found four factors to have an important and robust effect: erosion, damage due to the deterioration of the local environment, salinization, and soil fertility exhaustion from over-intense land use.

[8]The adjustment parameters fall on the diagonal of the R matrix.

[9]We currently have only 260 observations for the whole study period and there are 135 parameters to be estimated. If we were to divide the sample into two sub-periods, we would have negative degrees of freedom for estimating the model for the first period and only 24 for the second period.

[10]We interact a dummy with all own-price responses except for wheat. The own-price response parameter for wheat is not precisely estimated in the original specification; it has a t-ratio of 0.26, and varies widely when the model is specified differently. Other own-price response parameters are well-behaved when interacted with a dummy and are robust to different econometric specifications. The estimates for this specification can be found in de Brauw, Huang, and Rozelle (2000).

[11]We discuss measurement of the gains to market liberalization in the context of changes in profit levels when prices change. In fact, the changes in profit levels are also affected by changes in any exogenous factor.

[12]As we explain below, we use data for 1975-1995. However, we consider that the early reform period only occurred

between 1978-1984, when the household responsibility system was being implemented.

[13]Data were available for 13 provinces in North China (all provinces save Inner Mongolia and Qinghai).

[14]Provincial data before the early 1980s are not available from the State Statistical Bureau, so data before the early 1980s are from provincial yearbooks. We obtained a complete set of provincial statistical yearbooks from the library of the Agricultural Economics Institute of the Chinese Academy of Agricultural Sciences. These yearbooks have data back to the 1970s. One shortcoming of the provincial yearbooks that were released in the early 1980s was that its data series sometimes differed from those published in State Statistical Bureau publications. These discrepancies, however, were corrected in provincial publications that were published in the late 1980s. In this paper, since we use the most recent yearbooks (that is those from the late 1980s), our data series are the most consistent available.

[15]The prices for creating the cash crop output variable come from the Cost of Production Data. The price used as an explanatory variable for equations 2-5 is a national cash crop price index.

[16]Some people have questioned the reliability of the data, and criticized that it is based on a relative small sample size. A closer examination would indicate otherwise. In the 1990 enumeration, over 15000 households living in 2245 counties were questioned about their costs of production for the six major grain crops. Price Bureau officials claim that they have maintained a random selection process. Consistency in the data is maintained by carrying over respondents for an average period of three to four years. Data are self-recorded by the households.

[17]The signs of the environmental variables are consistent with those found by Huang and Rozelle (1995). The erosion and deterioration of the local environment effects are particularly harmful to other grains, crops grown in the most environmentally fragile regions.

[18]In our model, we are assuming that fertilizer is a variable input. Statistical tests show that by the mid-1980s, nearly 80 percent of adjustment was occurring in one year and by 1990 full adjustment was occurring. To the extent that fertilizer markets improved, our returns to market liberalization are understated, but because the improvements were only minor, these changes are negligible.

[19]We also tested the sensitivity of the dummy parameters to our assumption that the late reform period begins in 1985, by specifying the dummy variable interacted with the additive parameter as 0 for a longer time period and 1 for a shorter time period. We tested cutoffs for years 1986-1992, and found that the additive parameters were relatively smaller for other years and even statistically insignificant for some years. For example, the additive parameters were $R_{11D} = -0.01$ and $R_{22D} = -0.07$ if market liberalization is taken to begin in 1986 instead of 1985, and are statistically insignificant. If we calculated efficiency gains using these parameters, the gains to market liberalization would be markedly smaller.

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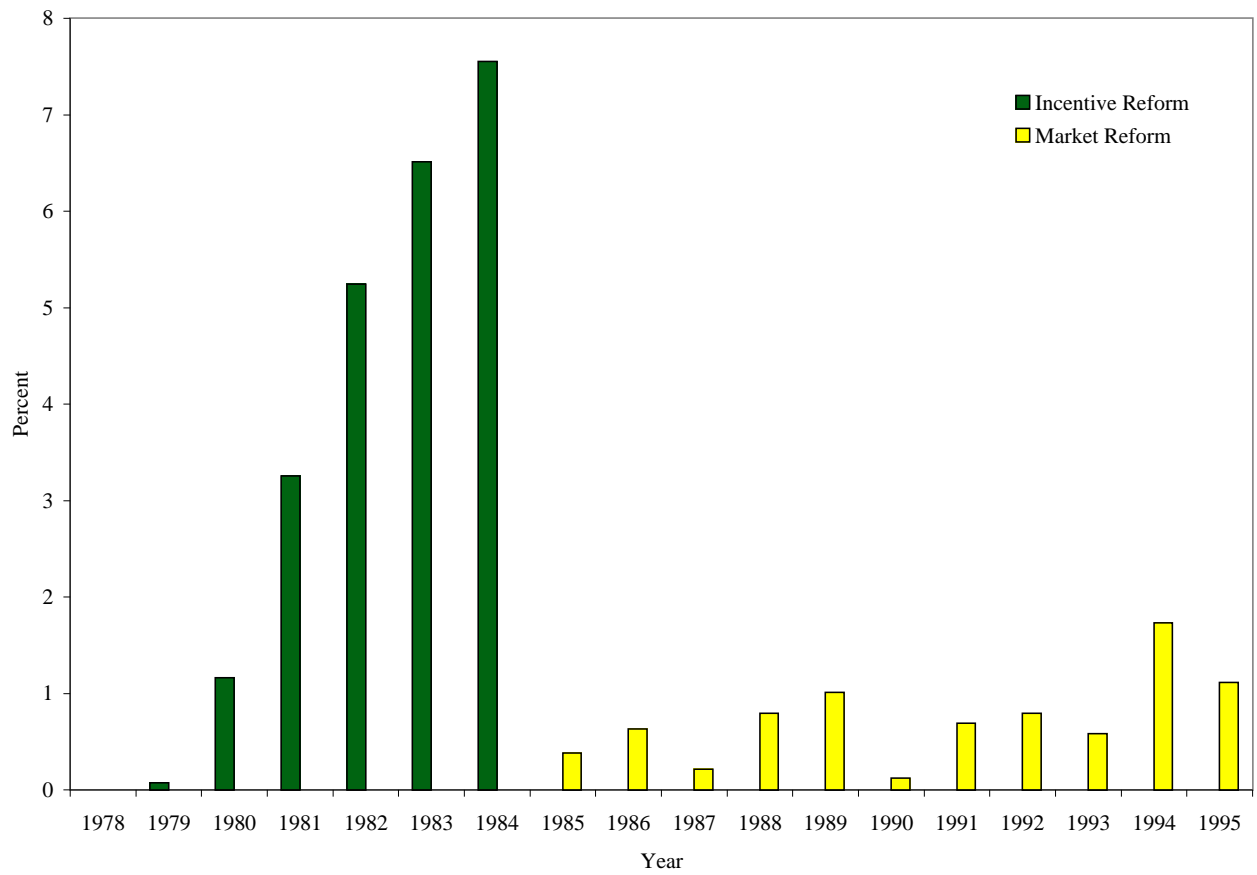
Figure 1: Gains to Reform in China's Agriculture

Table 1. Adjustment parameter estimates from non-linear, three-stage least squares estimator for Northern China

Parameter	Estimate
R_{11}	-0.16
	(3.65)
R_{22}	-0.35
	(8.38)
R_{11D}	-0.04
	(2.98)
R_{22D}	-0.25
	(5.49)

Notes: t-ratios in parentheses. The full set of parameter estimates are reported in Appendix B.

Table 2. Hypothesis testing for the presence of adjustment costs, quasi-fixity of inputs, and increase in the speed of adjustment

Hypotheses	Lagrange Multiplier Statistic
No adjustment cost or no quasi-fixity:	
(1) Crop Area	
$\quad$ ($R_{11} = -1$ and $R_{12} = 0$)	383.82**
(2) Agricultural labor	
$\quad$ ($R_{22} = -1$ and $R_{21} = 0$)	271.69**
(3) Both crop are and agricultural labor	
$\quad$ ($R_{11} = R_{22} = -1$ and $R_{12} = R_{21} = 0$)	663.31**
Independent Adjustment:	
(4) Crop area vs. agricultural labor	
$\quad$ ($R_{12} = R_{21} = 0$)	9.97**
No adjustment cost during market liberalization:	
(5) Crop area	
$\quad$ ($R_{11} + R_{11D} = -1$)	519.32**
(6) Agricultural labor	
$\quad$ ($R_{22} + R_{22D} = -1$)	28.71**
No increase in speed of adjustment post-HRS reform:	
(7) Both crop area and agricultural labor	
$\quad$ ($R_{11D} = R_{22D} = 0$)	25.50**

Notes: The ** indicates statistical significance at the 1% level. All test statistics are calculated from the non-linear three stage least squares estimates of the entire system of equations. The null hypothesis for the tests are in parenthesis.

Table 3. Changes in responsiveness of quasi-fixed and variable inputs: Own-price elasticity changes based on estimating changes in parameters across periods

Own-price elasticity of:	1975-84	1985-95
Sown Area	-0.001	-0.001
Labor	-0.013	-0.082
Fertilizer	-0.867	-0.467

Own-price elasticity of:	1975-89	1990-95
Fertilizer	-0.229	-0.446

Notes: Elasticities are calculated using a modification of the model that allows for the own-price response of each output or input to change for the later period (1985-95 or 1990-95). See de Brauw, Huang, and Rozelle (2000) for the parameter estimates that were used to calculate these elasticities.

Table 4. Estimated efficiency gains to HRS, increased responsiveness, and faster adjustment in the reform and post-reform periods

Year	(1) Incentive Reform Period Cumulative Percentage Return to Incentive Reform (I_t)	(2) Market Liberalization Reform Period Total Percentage Change in Returns due to to Market Reforms (G_t)	(3) Percentage Change in Returns due to Increased Responsiveness (R_t)	(4) Percentage Change in Returns due to Increased Flexibility (F_t)
1978	0.00	–	–	–
1979	0.07	–	–	–
1980	1.16	–	–	–
1981	3.25	–	–	–
1982	5.24	–	–	–
1983	6.51	–	–	–
1984	7.55	–	–	–
1985	–	0.38	-0.01	0.39
1986	–	0.63	0.21	0.43
1987	–	0.21	-0.20	0.41
1988	–	0.79	0.14	0.66
1989	–	1.01	0.30	0.70
1990	–	0.12	-0.42	0.54
1991	–	0.69	-0.25	0.94
1992	–	0.79	0.23	0.56
1993	–	0.58	0.05	0.53
1994	–	1.73	0.86	0.87
1995	–	1.11	0.48	0.63

Notes: Percentages are calculated by taking the estimated year-to-year gains and dividing by total estimated returns to land and labor.

Appendix

A Theoretical Model

Facing adjustment problems with a set of their quasi-fixed inputs (K), farmers are assumed to select optimal levels of variable inputs (L), their investment rate (I), and K, given the prices of output (p), variable inputs (w), and quasi-fixed inputs (q), and the level of external constraints. This maximization problem can be written as:

$$V(p, w, q, K, Z) = \max_{Y,L,I} \int_0^\infty \mathrm{e}^{-rt}(pY - wL - qK)\mathrm{d}t \tag{A.1}$$

subject to $\dot{K} = I - \delta K$, $K(0) = K_0 > 0$, and $Y = f(K, L, I, Z)$, where r is the discount rate, K is the net investment in quasi-fixed inputs, $K(0) = K_0$ is the stock of investment at the base year, and δ is a diagonal matrix with positive depreciation rates on the diagonal. The function, $f(\cdot)$, is a multi-product production function. Given the regularity conditions on $f(\cdot)$ and static price expectations, the value function in equation (A.1) satisfies the following Hamilton-Jacobi equation:

$$rV(p, w, q, K, Z) = \max_I \left[\pi^*(p, w, q, K, I, Z) - q^{'}K + V_K^{'}(p, w, q, K, Z)(I - \delta K)\right] \tag{A.2}$$

where π^* is variable profit, and V_K is the derivative of V with respect to K. Epstein (1981) has shown that by applying the envelope theorem to (A.2), the following equations for investment ($\dot{K}^*$), variable input derived demand (L^*), and output supply (Y^*) can be obtained:

$$\dot{K}^* = V_{Kq}^{-1}(rV_q + K) \tag{A.3}$$

$$L^* = -rV_w + V_{Kw}^{'}\dot{K} \tag{A.4}$$

$$Y^* = rV_p - V_{Kp}^{'}\dot{K} \tag{A.5}$$

where the lower case subscripts are used to designate derivatives.

B Parameter Estimates

Appendix Table B1. Parameter estimates of dynamic supply response system using non-linear three stage least squares estimator, Northern China

Parameter	Estimate	t-Ratio	Parameter	Estimate	t-Ratio
Θ_1	-45.25	0.73	H_{22}	-0.37	0.57
Θ_2	-148.27	2.54	IRR_1	0.0024	0.69
Θ_3	-494.11	1.41	IRR_2	-0.0069	2.16
Θ_4	-1799.31	2.16	IRR_3	-0.038	2.23
Θ_5	-2412.72	3.29	IRR_4	0.054	1.64
Θ_6	9.98	0.05	IRR_5	-0.0033	0.12
A_{11}	11574.59	0.26	IRR_{60}	0.81	3.87
A_{12}	71334.97	1.79	IRR_{61}	$5.70e-06$	0.36
A_{22}	73741.03	1.33	IRR_{62}	$1.64e-05$	0.48
A_{41}	-2.87	1.64	RES_1	0.36	1.78
A_{42}	-0.92	0.36	RES_2	0.95	5.00
R_{11}	-0.16	3.65	RES_3	0.40	0.33
R_{12}	-0.21	4.22	RES_4	6.76	3.10
R_{21}	0.12	1.64	RES_5	17.30	8.93
R_{22}	-0.35	8.38	RES_{60}	-21.69	1.25
R_{11D}	-0.04	2.98	RES_{61}	0.0059	1.74
R_{22D}	-0.25	5.49	RES_{62}	0.00095	0.22
G_{11}	0.14	0.03	HRS_1	-31.59	0.80
G_{12}	6.41	1.37	HRS_2	-140.71	3.84
G_{21}	-3257.79	1.30	HRS_3	564.06	2.50
G_{22}	-12412.82	4.69	HRS_4	927.59	2.31
L_1	-8.60	3.14	HRS_5	-684.74	1.92
L_2	2575.69	1.80	HRS_6	145.72	1.42
C_{11}	-0.001	0.73	DIS_1	-2470.11	2.38
C_{12}	0.54	0.93	DIS_2	-3141.24	3.51
C_{22}	879.83	2.32	DIS_3	-225.27	0.94
F_1	-31364.86	2.27	ERO_1	-660.72	1.71
F_2	-39668.19	2.52	ERO_2	-1247.29	3.74
B	52181.49	4.79	ERO_3	-74.67	0.81
N_1	-0.033	0.09			
N_2	-0.067	0.16	Objective Function$*N = 757.3$		
H_{11}	4.02	5.97	Provincial Dummies: Not reported		
H_{12}	0.68	1.18	Number of parameters: 135		
H_{21}	-2.19	2.89	Number of equations: 6		

Notes: $\Theta_i, i = 1, \ldots, 6$, correspond to intercepts in equations (3.2)-(3.5). The single letter parameters (e.g. A_{11}) correspond to matrices defined in equation (3.1), and the subscripts refer to the matrix position. The parameters $IRR_i, RES_i, HRS_i, DIS_i$, and ERO_i correspond to the estimates of T parameters in equations (3.2)-(3.5) and refer to the effects of the irrigation stock, research stock, household responsibility system, disaster index, and erosion index variables, respectively. The IRR_{6j} and RES_{6j}, $j = 1, 2$, parameters correspond to the T_{61} matrix in equation (3.5).

C Irrigation and Research Stock Calculation

C.1 Irrigation Stock Variable

The irrigation stock variable, $Z_i(t)$, is created on the assumption that the useful life of an irrigation system is 30 years. We apply the formula used by Rosegrant and Kasryno (1994) for creating an irrigation stock variable from expenditures:

$$Z_i(t) = \dot{Z}_i(t) + (1 - \delta)Z_i(t - 1) \tag{C.6}$$

where $\dot{Z}_i(t)$ are expenditures on irrigation in year t, and δ is the rate of depreciation of the stock. We experimented with a number of alternative depreciation rates and the results were robust to the different rates.

C.2 Research Stock Variable

Measuring the research stock is more complex, and must take into account longer lags which exist between the time of a research expenditure and the period in which it affects production. Furthermore, the stock depreciates over time. The research stock variable, $Z_r(t)$, is measured as:

$$Z_r(t) = \sum_{s=0}^{n} \alpha(t - s)\dot{Z}_r(t - s) \tag{C.7}$$

where n denotes the total time horizon over which research expenditures have an effect on production, and $\dot{Z}_r(t - s)$ denotes research expenditures in year $t - s$. We use a set of timing weights estimated by Pardey et al. (1992).