Short-Run Incentives and Myopic Behavior: Evidence from State-Owned Enterprises in China

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Abstract

How do performance incentives affect firm productivity? In 1978, Chinese industrial planners carried out major reforms of the compensation system in state-owned enterprises (SOEs), introducing bonuses which linked pay to measures of current work performance. Previous studies have argued that bonuses increased effort levels and led to large increases in productivity. However, incentives could have encouraged enterprises to overemphasize short-run targets and neglect long-range activities. To test whether incentives led to myopic behavior, I collect a unique panel of compensation, employment, and output statistics and use these data to estimate the short- and long-run effects of incentive use on labor productivity during the first decade of SOE reform, 1976 to 1988. The results indicate that productivity change was due to effort misallocation, rather than improvements in management. In the data, incentives were associated with a small increase in labor productivity in the short-run, and a large decrease in labor productivity in the long-run.

Introduction

In 1978, Chinese industrial planners reformed the compensation system in state-owned enterprises (SOEs), introducing bonuses which linked employee wages to the fulfillment of performance targets. Beginning in 1979 and continuing through the 1980s, incentive reforms were deepened by linking the total sum available for all forms of employee compensation to enterprise performance. Previous researchers have argued that these links increased effort levels in SOEs and improved enterprise productivity, but there are reasons to be skeptical of this interpretation. Since bonus distributions were based on ex-post observations of enterprise performance, the causal relationship between bonuses and productivity is difficult to disentangle. Past studies have not addressed this issue sufficiently. More importantly, tying wages to short-run outcomes does not necessarily strengthen incentives to improve long-run productivity. Past efforts in long-run activities such as maintenance, research, and training are important inputs in firms' current period production. Tying pay to short-run performance could encourage enterprises to neglect these activities in order to devote more effort to meeting current period targets. If this is the case, increases in short-run output associated with bonus use might have involved the sacrifice of future performance.

At the onset of the reform period, state-owned enterprises stood at the center of China's planned economy, producing 76 percent of gross industrial output and accounting for 57 percent of industrial employment in 1978. As part of the 1980s reform process, SOEs were granted the right to market any output they produced in excess of quotas set under the planning system. Simultaneously,

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the state allowed SOEs to distribute a portion of firm profits to managers and workers as bonus pay. Though SOE privatization and the growth of other sectors have reduced their relative importance, SOEs remain significant to the Chinese economy. Even as late as 2004, 38 percent of China's industrial output was produced in state-owned firms or corporations in which government entities held a majority stake (Li and Putterman 2008). As a result, the extent to which the provision of incentives for workers and managers can improve SOE productivity remains an important question.

Previous research has found that the introduction of bonus pay during the 1980s resulted in a large improvement in SOE productivity (Groves et al. 1994, Li 1997, Yao 1997). However, the persistence of these productivity increases over time has not been investigated. Unlike previous studies, I distinguish between the short- and long-run effects of bonus use on productivity. I measure long-run effects by allowing the use of bonuses over the past 10 years to influence current labor productivity. Incorporating past bonus use as a productivity determinant requires information spanning a long period. I collect a unique panel of compensation, employment, and output statistics from 977 SOEs in the Chinese iron and steel industry which covers 1949 to 1988, and use these data to evaluate the effect of bonuses on labor productivity from 1976 to 1988. A comparison of short- and long-run effects allows for a reevaluation of the supposed benefits associated with the introduction of bonuses. I find that the introduction of bonuses led to a small increase in mean labor productivity levels from 1978 to 1982, but a large decrease from 1984 to 1988.

Whether short-run incentives improve productivity depends on the types of activities workers perform. Workers subject to intense incentives often focus on rewarded activities to the exclusion of all else (Kerr 1975). For workers responsible for a single task, intense focus is generally beneficial. However, incentives may be less effective at motivating employees to take a holistic interest in their firm's success, particularly where they have multiple responsibilities. This problem was first formalized in Holmstrom and Milgrom (1991) who argued that the structure of conventional agency models, which assume that agents perform one task only, rather than 'multitask', had led economists to ignore the potential for incentives to distort behavior. In multitasking models, employees decide how much effort to supply and how to allocate it across multiple productive activities. Employers benefit from the full range of activities, but can only observe performance in a subset of them. Basing payments on these observations induces workers to withdraw effort from areas where performance is unobserved.

Some empirical studies have demonstrated that incentives can raise effort levels, while others have shown that incentives distort effort allocation. Lazear (2000) analyzes a windshield installation firm where labor productivity improved dramatically as a result of a shift from time to piece wages. Similarly, Shearer (2004) finds that tree planters are more productive under piece rate pay than time wages. Other authors have focused on more complex activities, where agents have more opportunities to engage in strategic behavior. In the Soviet Union, managers earned bonuses from 30 to 100 percent of their base salary for meeting monthly production quotas, and were frequently dismissed for failure. Berliner (1956) argues that these incentives created a vicious cycle of 'storming' to meet targets and the repeated deferral of maintenance. Oyer (1998) documents similar behaviors among US sales workers who aggressively discount products to meet revenue quotas, with negative consequences for future sales. Asch (1990) studies the behavior of navy recruiters subject to periodic performance assessments, and finds that recruiting success peaks at assessment time and falls off subsequently.

While these studies do demonstrate that incentives have both positive and negative effects, they provide little information about their relative magnitude. This information is crucial to understanding why some firms choose to use time wages to motivate workers, while others offer incentive payments. One way of addressing this issue is through comparison of the effect of incentives on performance in the short- and long-run. Measuring performance in long-run activities such as maintenance, research, and planning is generally harder than in short-run activities. When a considerable lag intervenes between when an activity occurs and its effects become evident, it can be very difficult to identify the responsible individuals and offer them appropriate rewards. Multitasking theory predicts that agents will exploit this asymmetry by focusing on improving current performance, and neglecting activities which only yield results in the future. This could lead principals to prefer time wages when they employ agents to perform a mixture of short- and long-run activities.

The effects of incentive practices on firm performance are difficult to identify empirically because managers choose compensation practices and their choices reflect firm and workforce characteristics. Private firms probably adopt performance-based pay only when they anticipate better results from this policy than time wages. It is thus difficult to separate effects due to unobserved firm characteristics from those due to incentives themselves. Resolving this issue requires identifying external circumstances which influence compensation practices and have a varied impact across firms, but do not affect firm performance. In market settings, this is very hard to do.

The Chinese case is exceptional because the decision to use performance-based pay was imposed by the government rather than chosen by firms. In 1978, provincial ministries carried out pilot schemes which limited the use of incentives to experimental groups of firms (Liaoning Wage Policy 1978). Subsequently, beginning with a pilot program in Sichuan in 1979, the government allowed firms to adjust their incentive structures, but their autonomy was greatly limited by compensation regulations which varied across provinces (Light Industry Research Group 1980, Koyima 1987). Later, in the early 1980s, pilot schemes were extended to the general population of enterprises, and by the mid-1980s adoption of incentive pay was essentially universal. Importantly, bonus policies varied across provinces and over time, meaning that the intensity of incentives was determined primarily by the firm’s regulatory environment and not by the anticipated effectiveness of incentives in individual enterprises. Within provinces, selection for experiments in the late 1970s provides another source of externally-imposed variation in compensation practices. These features make the Chinese SOE system an exceptionally good environment to test for causal effects of incentives on performance in the short and long-run.

To measure the dynamic impact of incentives on productivity, I estimate the effect of current and past use of bonuses on current labor productivity. I use the share of wages distributed as performance bonuses as a measure of incentive intensity. A major problem here, as in previous studies, is that the bonus share is influenced by firms’ ex-post performance. Firms with superior ex-post performance typically offer larger bonuses. This makes the bonus share an endogenous variable;

correlation between current performance and the bonus share includes a component due to reverse causation. I address the endogeneity issue using three methods, all of which yield similar results. In the first method, I exploit planners' selection of firms for the experimental introduction of incentive pay in 1978 as a source of exogenous within-province variation in the timing of incentive adoption. I compute a matching estimator which quantifies the effect of incentive introduction on short- and long-run growth in labor productivity. In the second method, I use a linear regression framework to estimate how labor productivity growth varied across firms as a function of current and past changes in wages and the bonus share. As part of reforms introduced during the early 1980s, enterprises aggregate wage funds were linked to measures of aggregate firm performance. However, firms varied in how they divided wage funds between bonuses linked to measures of individuals' current performance and promotions which were based primarily on workers' qualifications and experience. Interpretation of the regression results here is based on the assumption that the division of wage funds between bonuses and promotions was not correlated with other unobserved variables affecting firm productivity. Under this assumption, the regression measures how increases in the use of bonuses affected wage costs in the short- and long-run. If the decision to apply bonuses was related to productivity, the results from this regression would be contaminated by endogeneity. To address this possibility the third technique uses an instrumental variables regression that exploits province-level variation in the division of wages between bonuses and promotions. I argue that province-level variation reflected exogenously-determined attitudes of provincial bureaucrats rather than differences in enterprise productivity, and thus that provinces' mean bonus shares provide valid instruments for bonus policy.

Estimates from each technique indicate that firms which relied on bonuses had superior performance in the current period, but inferior performance in the long-run. The estimated long-run negative effects are large and imply that the expanded use of bonuses had a severe adverse impact on overall performance in the Chinese iron and steel industry. To quantify this impact, I use regression estimates to calculate the implied impact of actual bonus use on labor productivity in 1988 relative to the counterfactual that bonus use was avoided entirely. These calculations indicate that the use of bonuses decreased 1988 labor productivity by between 0.16 and 0.45 log points, with the magnitude of the estimate depending on which regression specification is used to compute the counterfactual. Matching estimates of the treatment effect of adopting incentives in 1978 also suggest large negative effects in the long-run. The matching estimates indicate that firms which delayed implementation of incentives had superior long-run performance to firms which adopted incentives in 1978. Over the course of the decade between 1978 and 1988, mean cumulative labor productivity growth was 0.17 log points lower in firms which adopted incentives in 1978 than it was in otherwise similar firms which adopted incentives later.

I divide my discussion into six sections. First, I present a simple example of a multitasking agency relationship in which excessive rewards for current performance distort decision-making and lead to decreases in long-run output. I relate this prediction to the behavior of a Chinese iron and steel firm which appears to have responded to incentives as the model predicts. This raises the question of why such rewards may be put in place even when they lead to inefficient outcomes. To explain this political economy issue, I discuss governance problems in the Chinese SOE system which made it difficult for the central government, the principal in this setting, to control enterprise-level policies and encouraged lower level government agencies to establish inefficient incentive practices. The third section discusses methodological problems in previous studies of bonus use in Chinese SOEs, in particular their lack of adequate controls for reverse causation and their failure to distinguish short- and long-run effects. One of the factors hindering previous studies has been the lack of a set of panel data with an adequate time dimension. In the fourth section, I describe the collection of a novel large-scale dataset which makes it possible to study incentives in a dynamic context. Past studies have linked bonus adoption to acceleration in the growth of SOE productivity during the 1980s relative to growth during the 1960s and 1970s. The fifth section places changes in bonus use in the context of other policy changes which occurred during the 1980s. I argue that improvement in SOE performance during the 1980s likely reflected improvements in social stability and the resumption of policies dating from the 1950s, rather than the effects of incentives. The sixth section presents statistical results indicating that performance-based compensation had a negative effect on long-run productivity. Finally, I conclude the paper by reviewing my findings and their implications for the study of incentive use in other settings.

A Simple Multitasking Example

Before considering the specifics of Chinese incentive policy, I construct a very simple multitasking problem which illustrates why production incentives can have negative effects on future performance. The model is in the same spirit as Holmstrom and Milgrom (1991) in that agents respond to incentives by misallocating effort, but differs in that I assume that agents are intrinsically motivated. Other papers considering intrinsic motivation and incentive use include Benabou and Tirole (2003), Predndergast (2008), and Besley and Ghatak (2005). All of these papers analyze settings where intrinsic motivation and incentives are substitutes, whereas I analyze a case where they are complementary. In my model, highly-motivated agents are less prone to misallocate effort when tempted with an incentive, and thus the principal can offer them much larger incentives. Previous researchers have argued that incentives had a powerful positive effect in China because initial motivation levels were quite low (Groves et al. 1994). The model considers a case where strong incentives have negative effects in the presence of weak motivation, but positive effects when offered to motivated agents. The model follows:

A principal hires an agent to undertake production and investment for a finite period.[2] The principal's goal is to induce the agent to maximize the sum of production and investment. Output in production is contractible, whereas output in investment is not observable and thus not contractible. The agent is intrinsically motivated, meaning that he receives utility which is a fraction $m \in [0,1]$ of the sum of production and investment. As an additional motivator, the principal can offer the agent a bonus, $b \in [0,1]$, which is a share of production output. Basing his decision on the size of the bonus offered, the agent allocates an effort level, $e_q \in R_+$, to production, and an effort level, $e_i \in R_+$, to investment. Production and investment output, $Q \in R$ and $I \in R$, respectively, are logarithmic functions of effort which are allowed to take negative values. Negative investment can be interpreted as the

[2] An analogous model could be written where agents are employed repeatedly, but face an exogenous probability of contract termination. Alternatively, the model could be based on a team of agents who can verify individual production efforts to the principal but cannot verify individual investment efforts. In the team context, production incentives create a free-riding problem in investment.

transformation of the firm's existing capital stock into production output. Total output, denoted Y, is a concave function of the agent's effort levels as shown in equation (1.1).

$$Y(e_q, e_i) = Q(e_q) + I(e_i) = \ln e_q + \ln e_i \quad 1$$

The agent incurs an effort cost C which is a convex function of the agent's effort levels as shown in equation (1.2).

$$C(e_q, e_i) = \begin{cases} 0 & if \quad e_q + e_i < 2 \\ (1/2)(e_q + e_i - 2)^2 & otherwise \end{cases} \quad 2$$

The agent's problem is to choose effort levels which maximize his utility, as shown in equation (1.3).

$$\max_{e_q, e_i} \{(m+b)Q(e_q) + mI(e_i) - C(e_q, e_i)\} \quad 3$$

Since the agent's utility is a concave function of his effort level, his optimal effort choices are given by the first order conditions of equation (1.3). The agent's optimal effort level for each activity, together with his aggregate effort level, e, is shown in equation (1.4).

$$\begin{aligned} e(m,b) &= e_q(m,b) + e_i(m,b) = 1 + \sqrt{2m+b+1} \\ e_q(m,b) &= \frac{m+b}{2m+b} e(m,b) : e_i(m,b) = \frac{m}{2m+b} e(m,b) \end{aligned} \quad 4$$

The conditions in equation (1.4) indicate that the principal faces a trade-off. Increasing the bonus level will increase the agent's overall effort level, but also induce him to reduce investment effort. The reduction in investment is more severe when the agent is poorly motivated, and thus places a low weight on investment output. The principal's objective is to choose a value of $b \in [0,1]$ which maximizes total output, as shown in equation (1.5).

$$\max_b \{Y(e_q(m,b), e_i(m,b)\} = \max_b \left\{ \ln(\frac{e_q(m,b)e_i(m,b)}{e(m,b)}) + \ln(e(m,b)) \right\} \quad 5$$

In equation (1.5), the first term, $\ln(\frac{e_q(m,b)e_i(m,b)}{e(m,b)})$, which is decreasing in b, measures loss in aggregate output from misallocation. The second term, $\ln(e(m,b))$, measures gains in aggregate output from increases in the agent's total effort level, $e(m,b)$. The first order condition for maximizing output implies that the principal chooses a bonus level of $b=m^2$.[3] This indicates that the optimal

[3] The principal's objective function, given in equation (1.5), is not concave on $b \in [0,1]$, but is quasi-concave on this interval. To verify quasi-concavity and thus that $b=m^2$ is the unique maximum, note that

strength of incentives is increasing in the agent's motivation level, m. Since motivated agents internalize more of the costs of misallocation, principals can offer them more intense incentives. This is relevant to the context of Chinese SOEs because SOE managers and workers are often regarded as unmotivated and prone to shirking. The multitasking model presented here indicates that offering intense incentives to poorly motivated agents could lead to shirking in long-run activities, and thus that bonus provision could have had negative effects on SOEs' overall performance.

To illustrate the applicability of this model to the Chinese bonus system, it is worthwhile to discuss the experience of the Handan Steel Company as described in collected papers from a steel industry conference (The Reform of Small and Medium Iron and Steel Enterprises 1987). The incentive system at Handan was similar to that at most SOEs. From the early 1980s, Handan allocated a fixed fraction of its after-tax profits to a bonus fund, with the fraction set by province-level guidelines. Handan's managers could design some incentives for their own employees, but distribution of these rewards was always contingent upon the firm meeting monthly profit and sales targets set by provincial authorities. In the mid-1980s, Handan's managers were struggling to meet these targets and faced a dilemma. Their existing investment plan called for the construction of a steel rolling facility which would allow the firm to manufacture more sophisticated products in the future. Managers anticipated that continued investment in the facility would make it impossible for the firm to meet profit and sales targets, and thus distribute bonuses. To avoid this, managers decided to put the project on hiatus and sell off construction materials. The revenue generated, either through the sale or through the reallocation of labor, allowed the firm to fulfill production targets and distribute bonuses. This outcome is consistent with the basic prediction of the model; Handan withdrew resources from investment to meet production targets. Implicitly, such a transfer should boost current output, but detract from output in the future.

SOE Governance in China

Multitasking models show that strong incentives can be inefficient, but do not explain why a firm might choose to implement them anyway. Models often assume that firm owners are sufficiently informed to control compensation practices directly. In practice, owners delegate control rights to a corporate board to represent their interests. Board members often have personal connections to managers, which can limit their willingness to aggressively pursue the interests of firm owners. Under weak oversight, managers may be able to negotiate a compensation contract which rewards self-dealing. Since the influence of long-term activities on firm value is difficult to assess, compensation contracts tend to reward increases in short-run earnings more heavily than changes in firm value. The danger is that strong incentives to increase earnings will encourage managers to undertake activities that produce short-run results, but do not create value for owners.

$$\frac{dY}{db} = \frac{-2(b-m^2) - b\left(\sqrt{(m+1)^2 + (b-m^2)} - (m+1)\right)}{\sqrt{b+2m+1}\left(1+\sqrt{b+2m+1}\right)(b+m)(b+2m)}$$

is strictly positive for all $b \in [0, m^2)$, equal to zero for $b = m^2$, and strictly negative for all $b \in (m^2, 1]$.

In the Chinese SOE system, ultimate ownership resides with the central government, and managerial supervision is performed by province-level state agencies. Since future performance is difficult to assess, bureaucrats employed in supervisory agencies are evaluated for promotion on the basis of the current performance of the enterprises they supervise. Firm managers themselves are often selected from within the province-level bureaucracy. Given their tight links to management and their lack of an ownership interest, bureaucrats may choose to implement short-run incentives which encourage managers to engineer short-run improvements in firm performance, either by making short-run decisions or manipulating financial data. For the central government, it may be difficult to distinguish a short-run increase in a firm's apparent performance from a lasting contribution to firm value. As a result, the central government is ill-equipped to assess the effects of incentive policies.

Besides regulating the level of incentive use, provincial agencies are also responsible for ensuring that enterprises meet performance targets. Though promotion opportunities encourage agency bureaucrats to perform this function, they may be less scrupulous about monitoring enterprise performance in investment-related areas. In order to short-term performance targets, managers often sacrifice the future of the enterprise by engaging in asset-value-reducing activities (Qian 1996). Bureaucrats may be unwilling to reveal these activities to the central government because their career prospects are linked to short-run enterprise performance, and because they have strong personal connections to enterprise managers.

Existing Studies of the 1980s Incentive Reform: The Endogeneity Problem

Existing studies have found that incentives had a positive effect on performance, but these studies suffer from some methodological problems. Econometric studies using the 1980-1989 Chinese Academy of Social Sciences (CASS) survey of 769 SOEs in four provinces, including those of Groves et al. (1994), Li (1997), and Yao (1997), have found that the introduction of bonuses improved enterprise productivity. The CASS data are based on responses to a survey sent out by the State Reform Commission to enterprises and includes firms from most industries. One concern with the use of the CASS data is that participating firms were not selected randomly; participants were larger than average and had faster labor productivity growth than the national SOE average. The reform effects which researchers are interested in are those in the general population of SOEs, but these could potentially differ significantly from those in samples selected by Chinese government agencies.

Studies using the CASS data estimate production functions incorporating measures of bonus use and other institutional controls as productivity determinants. Since planners essentially distribute ing bonuses across firms on the basis of performance, the potential for reverse causation in these regressions is serious; the failure to observe all factors affecting productivity could easily lead to a positive coefficient on bonuses even they are irrelevant or harmful to performance. Solving this problem requires identifying a valid instrument for bonus use, but the instruments proposed in most studies are not convincing. Groves et al. (1994) and Yao (1997), for example, use a one-period lag of bonus payments as an instrument, but since a firm's recent performance—as reflected in recent bonus payouts—is positively correlated with current performance, this strategy is likely to bias estimates of the effects of bonus use upwards. Li (1997) argues that changes in planner-determined output quotas are set through a political process and not on the basis of firm productivity, and uses these allocations as instruments. However, this argument seems dubious because both managers and planners observe performance-related information and must factor this in when negotiating output quotas.

A second, potentially even more important, problem with these studies is that they focus only on short-run outcomes. The focus of past studies on the short run could be due to the limited time coverage of the CASS dataset, which includes only ten years of information. In a short panel, incorporating a firm's historical use of incentives as a performance determinant greatly reduces the sample size, and thus the power to test hypotheses. Omitting historical data on incentive use, however, may yield misleading results. To resolve this issue, I collect a very long panel containing up to 40 years of information, which allows me to condition on each firm's historical compensation practices without significantly reducing the sample size.

The Dataset

The data I collect come from Chinese sources which have never been used before by Western scholars. For ease of reading, I translate their titles into English in the text; Chinese titles are given in the bibliography. The principal source of data is a three-volume set of plant level wage statistics for the iron and steel industry, *Chinese Smelting Industry Labor and Wage Statistics, 1949-1988, Vols. 1-3 (1990)*, hereafter CSILWS, which was compiled from firm records by the Ministry of Metallurgy for internal government studies of the effectiveness of performance incentives. This source provides long-run historical data on nearly every SOE which operated in the iron and steel industry in 1988. Due to concern about the reliability of output measures from design and construction firms, I focus on 977 mining and manufacturing firms which produced standardized commodities, excluding 123 units engaged in planning, construction, research, and education. The range of commodities produced include mineral ores such as iron, manganese, and fluorite, intermediate products such as coke, pig iron, and steel ingots, and final goods such as finished steel and smelting machinery.

The CSILWS data contain observations of gross output per worker, measured in constant 1980 prices, together with physical data on labor productivity measured in the tonnage of the firm's three principal outputs. I use gross value of output per worker as measure of firm performance. Since the gross value of output is based on a constant pricing weighting of all the firm's products, it is a physical measure of the firm's output. In theory, value-added is a better measure of output than gross value. However, during the 1980s SOEs often underreported the cost of inputs purchased on credit in order to over report current period value-added and profit. Since state marketing agencies purchased most iron and steel goods, the physical quantities produced by each firm were much more difficult to misreport. I control for variation in the share of value-added in gross value across firms through the uses of fixed effects, product variety-specific time dummies, and (in one specification) firm-specific time trends. Product variety-specific time trends also capture prices changes which may affect firms differently depending on which product they produce. Wage data indicate total compensation, as well as the amounts paid on a time, piece, and bonus basis. I analyze the incentive effects of both piece rates and bonuses, but focus primarily on bonuses since they were the predominant form of performance-based pay during the 1980s. Employment data includes total employment, employee sex, occupation (management/supervisory, technical, shop floor worker, trainee, service), and contractual status (permanent, contract, temporary). These are useful controls since technical and managerial workers are more likely to receive bonus-based compensation and shop floor workers piece-based compensation, and differences in employee composition could affect firm performance independently of the compensation structure. In addition to the quantitative variables directly provided in the dataset, I code 16 dummies for product varieties in which at least 10 enterprises specialize (for example, coke, iron ore, pig iron) and use a miscellaneous category to capture the remaining varieties.

The principal defect of the CSILWS dataset is that it does not contain data on the capital stock. These data are difficult to obtain and I was only able to gather information for 216 firms, which are either larger firms or firms located in the provinces of Sichuan, Jilin, Henan, Jiangxi, or Shandong. Since reliable data on investment and capital goods prices are unavailable, I rely on book values of the capital stock net of depreciation to measure differences in capital intensity across firms. I compile data on the capital stock from other internal government sources. These sources allow me to crosscheck the CSILWS statistics using other government sources publishes in different years. The sources are as follows: *Local Medium and Small Iron and Steel Enterprises Historical Financial Statistics (1983)*, *Smelting Industry Enterprise Financial Statistical Materials, Vols. 1 and 2 1985-1990 (1992)*, *Smelting Industry Enterprise Financial Statistical Materials, Vols. 1 and 2 1949-1978 (1979)*, *Reform of Small and Medium Iron and Steel Enterprises, 1979-1987 (1988)*, *Liaoning Smelting Industry Production and Labor Statistics (1962)*, *Sichuan Smelting Industry Financial and Cost Statistics 1950-1985 (1987)*, *Hunan Smelting Industry Statistical Materials,* 1949-1976 (1977), *Shaanxi Smelting Industry Statistical Materials, 1949-1977 (1978)*, *Guizhou Smelting Industry Statistical Materials, 1949-1976 (1977)*, *Jilin Smelting Industry Statistical Materials 1949-1980 (1982), Henan Smelting Industry Statistical Materials 1979-1985 (1988), Jiangxi Smelting Statistical Materials 1949-1990 (1991)*, *Shandong Smelting Industry Statistical Materials 1980-1985 (1986) and 1986-1990 (1991)*, and *Fifty Years of the Chinese Iron and Steel Industry Statistical Compendium, Vols. 1 and 2 (2003).*

With the exception of the last compendium, the data were compiled for internal government use, not for public release. The use of data from these sources has two significant advantages. Firstly, the firms under analysis constitute essentially the entire population of iron and steel firms, rather than a nonrandom sample selected by a government agency. This avoids selection bias, often a concern in previous studies which relied on samples released by state agencies. Secondly, the availability of multiple government sources dating from different time periods allows an assessment of the consistency of government data over time. In crosschecking, I find that internal government sources are generally consistent with one another, regardless of when they were compiled. Publically released plant-level data, however, such as statistics in *Fifty Years of the Chinese Iron and Steel Industry Statistical Compendium, Vols. 1 and 2 (2003)*, report some investment, capital, and employment figures for the pre-reform period which are inconsistent with internal government sources and seem implausible.[4] In addition, aggregate-level data in publically released yearbooks, while apparently accurate, do not include information on input use in 1953-1956, 1958-1961, 1963-1964, 1966-1969, and 1971-1974. Previously, no input statistics have been available for any of the above periods, at either the plant- or the aggregate-level for any industrial sector.

Collection of the data allows assessment of productivity trends in the post-reform period relative to trends in earlier periods. A striking feature of the data is that radical changes in labor productivity occurred several times prior to the onset of enterprise reform. These breaks in trend were contemporaneous with changes in compensation policy, technology policy, and political disruptions. Since similar changes in planning policy also occurred during the late 1970s and early 1980s, the data raises questions about how important these policy changes were relative to novel efforts to reform SOE management such as the expansion in incentive pay.

A Long-Run Perspective on Policy Changes and Productivity

Studies of productivity growth in Chinese SOEs often focus on novel institutional reforms, such as rapid expansion in the use of bonuses, as a key driver of growth. A basic assumption underlying these studies is that changes driving labor productivity growth during the reform period differed from those in earlier periods. Reforms during the 1980s, however, should be viewed in the context of earlier shifts in economic policy. Many of the major policy changes which began in 1978 had precedents in policies pursued during prior decades, in particular the early- to mid-1950s. During these periods, Chinese planners made use of promotions based on skills and education to motivate workers, limited the rate of employment growth in state industry, and imported foreign technologies on a large scale. These policies are likely to have had a positive effect on productivity, and could be sufficient to explain why growth in labor productivity during these periods was relatively rapid.

In general, labor productivity in Chinese industry grew during periods of relative stability, such as the Postwar Recovery Period (1949-1952), the First Five Year Plan Period (1953-1957), the Post-Great Leap Forward Stabilization Period (1962-1965), and the Early Reform Period (1978-1988). However, during chaotic periods associated with extreme leftist movements, such as the Great Leap Forward (1958-1961) and the Cultural Revolution (1966-1976), productivity collapsed, erasing earlier achievements. Since extreme leftist policy makers opposed incentive pay, incentive use also fell during these periods. In Figure 1, I use the CSWILS data to show these trends in the Chinese iron and steel industry, graphing both aggregate log labor productivity and the percentage of wages distributed as bonuses and piece rates. Several major shocks to productivity are evident; sudden collapses in productivity occurred in 1958 and 1967, and recoveries occurred in 1962 and 1977. Though incentives were also applied during other stable periods, the extent of incentive use in the 1980s was

[4] For example, the Great Leap Forward (1958-1961) was associated with a rapid influx of agricultural labor into the iron and steel industry. Internal government sources document a ten-fold increase in the iron and steel labor force in 1958, whereas the publically released compendium does not show any jump in employment levels in this year.

unprecedented. The very low level of incentive use during the Cultural Revolution reflects the aversion of extreme leftist leaders to material incentives.

Leftist movements had major impacts on industry independent of their influence on bonus use. They affected technological borrowing, the growth rate of industrial employment, and the availability of promotion-based wage increases. During the First Five Year Plan (FFYP), China purchased advanced iron and steel technologies from the Soviet Union on a large scale (Clark 1973). Throughout Chinese industry, most machinery installed during the 1950s was imported from the Soviet Bloc.[5] In 1956, Sino-Soviet relations began to deteriorate, and after 1960 the Soviets withdrew all technological assistance. To a significant extent, the collapse in technological cooperation reflected Soviet disapproval of the extreme leftist development strategy that Chinese policy makers adopted in the late 1950s. During the 1960s and early 1970s, China relied almost exclusively on domestic capital equipment. Large-scale technological borrowing resumed at the onset of the reform period in 1978, this time with the US, Japan, and Europe as the key source countries. Like shifts in the use of incentives, changes in technology imports correlate closely with productivity trends. Periods of rapid borrowing during the early to mid-1950s and after 1978 coincided with accelerated productivity growth.

Shifts in the government's objectives with respect to wage and employment growth were a second channel through which politics affected China's industrial development. Faced with a limited agricultural surplus, planners had to choose between funding increases in industrial employment and skill-based promotions for incumbent workers. Extreme leftist policy makers favored rapid employment growth and wage restraint, while rightist policy makers advocated a closer adherence to the strategy recommended by Soviet advisors, emphasizing capital-intensive technologies and the provision of skill- and education-based wage increases. From 1953 to 1957, the heyday of Soviet influence, the absorption of rural labor was held to a modest pace and industrial workers were offered the opportunity to earn significant wage increases through skill-based promotions. With the onset of the Great Leap Forward in 1958, leftist policy makers rejected Soviet advice, transferring a significant fraction of the rural population into industrial occupations. In the iron and steel industry, aggregate employment jumped from 400,000 in 1957 to 4 million in 1958, returning to a sustainable level of 700,000 only in 1962. Excessive iron and steel employment had a large, negative effect on food security (Li and Yang 2005). During the next three years, the government returned to offering workers promotion opportunities and avoided increases in the industrial labor force. In 1966, the onset of the Cultural Revolution marked a return to the leftist emphasis on industrial employment growth. To decrease the likelihood of an agricultural crisis, increases in the industrial labor force were accompanied by draconian controls on industrial wages. From 1966 until 1976, promotions essentially did not occur, so that new entrants to the labor force had little incentive to acquire skills. At the onset of the reform period in 1978, promotions resumed and renewed emphasis was placed on skills and education as criteria (Shirk 1981).

Analysis of performance and political changes prior to 1978 raise significant questions for the interpretation of SOE reforms during the 1980s. Political stability, access to technology, and the use of

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[5] For aggregate statistics on the installation of capital equipment and the import of machinery by source country, see *Machinery and Electronics Historical Statistics 1949-1984* (1985).

promotions are all likely to have played key roles in the relatively successful performance of SOEs during the early-to-mid 1950s and the mid-1960s. One important question is whether positive developments in these areas can also explain improved performance during the 1980s. In particular, it is not clear whether labor productivity growth resumed during the 1980s because SOE workers and managers were provided with bonuses, or because of increases in technological borrowing, the use of promotions, and enhanced political stability. Though a statistical treatment of these issues is beyond the scope of this paper, they should be kept in mind when interpreting the results related to incentives. The key point here is that the use of the Cultural Revolution as a reference period to understand the effects of specific post-1978 reforms is problematic. Many disruptive events occurred during the Cultural Revolution, and the cessation of performance-based pay was likely a comparatively minor issue.

Specifications and Results

In the long run, change in labor productivity is primarily driven by technological progress and the accumulation of physical and human capital. Whether rewards for current performance accelerate productivity growth depends on whether they strengthen incentives to undertake these activities. If offering bonuses for short-run performance induces a neglect of long-term activities, then incentive use could have a negative effect on future labor productivity. Here, I present three statistical tests which show that firms with a larger share of bonuses in total wages experienced increased labor productivity growth in the short-run, but had inferior labor productivity growth in the long-run. Endogeneity is a significant concern here because the share of bonuses in wages was directly influenced by performance outcomes—high productivity firms were allowed to distribute more bonuses. As a consequence, the empirical relationship between bonus levels and firm performance reflects both the influence of bonus opportunities on behavior and correlation between bonus levels and firms' productivity.

Each of the three methods attempts to identify the effects of bonuses on behavior separately from the correlation of bonuses with firm performance. Though each method exploits different sources of variation in bonus use, they all yield the same qualitative result: bonus distributions increased current period productivity and reduced productivity in future periods. In the first method, I compare short- and long-run labor productivity of firms based on whether they adopted either bonuses or piece-rates in 1978, or adopted them in some later year. Unlike in later years, bonus or piece-rate adoptions in 1978 were intended to be experimental and were not based on ex-post performance. As a consequence, changes in bonus and piece use in 1978 were plausibly uncorrelated with unobserved firm characteristics that affect productivity and the estimated short- and long-run effects of adopting incentives in 1978 can be interpreted as causal. In the second method, I use a first differenced panel regression to estimate the effects of changes in the share of bonus payments in total wages on current and future labor productivity. Unlike the first method which uses variation in incentive use from one year only, the first differenced regression makes use of variation in bonus use throughout the 1970s and 1980s. During the 1980s, provinces set quotas for firm-level average wages and bonus distributions based on ex-post realizations of firm performance. To control for endogenous bonus setting, I use firm-level wage changes to proxy for unobserved variables which provinces used to determine these quotas. This is a control function approach, and is related to the production function estimation technique introduced in Olley and Pakes (1996). In the third method, I use an instrumental variables regression to test whether the short- and long-run effects of bonus use on labor productivity were predicted by the size of the bonus offered or were common to all firms using bonuses of any size. If estimated long-run effects are due to behavioral distortions, one would expect larger bonuses to be associated with larger long-run effects and this is what my findings show. The instruments here are based on differences in bonus policy across provinces. To exploit policy differences as a source of identification, I compute an average bonus level in each province and use this as an instrument for the firm-level bonus share.

The first approach relies on variation in incentive use circa 1978, one year before policymakers began directly linking bonus distributions to firm performance. In 1978, the Chinese government instructed provincial agencies to select some firms under their jurisdiction for experimental use of incentives. As a result, 40 percent of firms in the iron and steel industry shifted from no use of incentives to some use of either bonuses or piece rates in this year. The intention of this policy was to gather information on the effects of incentive use, and provincial bureaus were encouraged to include firms with a broad range of initial performance levels in this experiment (Liaoning Wage Policy 1980). However, provinces also knew that the central government expected a positive outcome, and overrepresented firms with a history of superior performance to ensure that participating firms would be able to report higher average productivity levels (Shirk 1993). In terms of interpreting policy effects, selection based on past performance does not pose a serious problem because it is observed prior to the onset of the policy change. By using past trends as control variables, differences in productivity due to the change in bonus policy can be separated from those associated with non-random selection.

I estimate how participation in the experiment in 1978 affected firms' short- and long-run labor productivity using the bias-corrected matching estimator due to Imbens and Adabie (2006), which was coded into a Stata algorithm in Adabie et al. (2004). This nonparametric estimator can be understood as specifying two potential outcomes for each firm depending on whether the firm adopted bonuses, piece rates, or both bonuses and piece rates in 1978, and is thus in the participating group, or did not adopt incentives at this time, and is thus in the nonparticipating group. The underlying assumptions of the model are: first, after controlling for observables, selection for participation is random; and second, conditional on their observed characteristics, all firms have some positive probability of participation. For each firm *i*, the estimator evaluates two potential outcomes at time *t*: $Y_{it}(1)$, the outcome conditional on participation, and $Y_{j(i)t}(0)$, the outcome conditional on non-participation. Firms in the participating and non-participating groups are matched on the basis of a similarity of a set of observed characteristics, Z_i, where similarity is calculated on the basis of the distance norm described in Adabie et al. (2004). The parameter of interest is the average treatment effect, or the average difference between $Y_{it}(1)$ and $Y_{j(i)t}(0)$ in the population. This is computed by matching each treated firm *i* with a similar untreated firm *j(i)*, and calculating the difference in their outcome variable, τ_{it}. The τ_{it}s calculated from each match are averaged to generate an estimate of the average treatment effect in the population, $\hat{\tau}_{it}$. The estimator is summarized below in Equation 6:

$$\hat{\tau}_t = \frac{1}{n}\sum \tau_{it}\left(Z_i\right) \text{ where } (\hat{\tau}_{it}(Z_i) = Y_{it}(1) - Y_{j(i)t}(0) \mid Z_i = Z_{j(i)}) \qquad 6$$

Potentially, bonus and piece-rate adoption in 1978 could be correlated with unobserved firm characteristics and this correlation could bias the estimates obtained from Equation 6. If firms self-selected into the experiment, one would expect the participating firms to have production processes or management structures which were better suited to the use of bonuses than those of the non-participating firms. If this were the case, then one would expect differences in bonus use between participating and non-participating firms to persist over time. If, on the other hand, selection criteria were unrelated to unobserved characteristics, one would expect participating and non-participating firms to converge to similar levels of bonus use once the experimental period was completed and the use of bonuses was extended throughout the SOE system. To test whether self-selection was important in this experiment, I use the matching estimator shown in Equation 6 to test if participating firms had persistently higher levels of bonus use. I specify the outcome variable as the share of bonus payments in wages in year t, where $t \in \{1978, \ldots, 1988\}$. In the set of variables used to define matches, Z_i, I include categorical variables which are constant over time, including the firm's founding year and the firm's product type, as well as the 1973 to 1977 levels of a set of dynamic variables related to firm labor productivity, size, compensation practices, and labor force composition.[6] The estimated average bonus share for the participating and nonparticipating groups is shown in Figure 2. Not surprisingly, participating firms had significantly higher levels of bonus use in 1978 and also in the two subsequent years, 1979 and 1980. Afterwards, as incentive use was extended to the broader population of firms, the average bonus share in the participating and non-participating groups converged to similar levels. This indicates that self-selection is unlikely to have played an important role in the adoption of incentives in 1978, and supports the interpretation of incentive adoption in 1978 as resulting from a quasi-experimental process.

If bonus adoption was associated with increased effort in current period production and reduced effort in long-run activities, then labor productivity growth among participating firms should have exceeded that in non-participating firms when participating firms used bonuses more intensively (1978, 1979, and 1980), but have fallen behind those of non-participating firms once levels of bonus use in the two groups of firms converged to similar levels. To test this, I evaluate the matching estimator shown in Equation 6 conditioning on the same matching variables, but measuring outcomes as cumulative labor productivity change between year t, where $t \in \{1978, \ldots, 1988\}$, and a common base year, 1977. Because I am including past labor productivity levels as matching variables, the estimation controls for firm-level labor productivity trends which predate the 1978 shift in compensation practices. The results, shown in Figure 3, provide support for the hypothesis that incentive use had negative long-run effects on labor productivity. By 1986, participating firms exhibited a large deficit in labor productivity growth relative to non-participating firms, and the effects are significant at the 5 percent

[6] The variables are as follows: the firm's labor productivity levels in each year from 1973 to 1977, the average nominal wage paid to firm workers in each year from 1975 to 1977, the number of employed in each year from 1975 to 1977, the percentage of workers of the parenthesized classifications in 1977 (managerial, technical, trainees, service, contract, temporary, female). I also include the percentage of wages distributed as bonuses and piece rates in 1975. Including the use of incentive pay in 1977 would violate the assumptions of the model because firms which used incentives in 1977 were ineligible for participation in 1978. Firms which used incentive pay in 1975 were eligible for participation because 2 of the 70 firms in this category stopped using incentives in 1976 or 1977, and 1 of these 2 resumed incentive use in 1978 and is thus in the participating group.

level. In 1988, ten years after the onset of treatment, cumulative labor productivity growth in participating firms was 17 percentage points lower in log terms than that in similar non-participating firms. Though the differences are not statistically significant, the estimates also suggest that incentive adoption had positive effects on labor productivity in the short run. From 1978 to 1980—the only years when the participating group had significantly higher levels of bonus use—cumulative labor productivity growth in participating firms exceeded that of nonparticipating firms by between four and six percent in log terms.

The matching estimates provide evidence that early adoption of bonuses was associated with negative long-run effects, but do not establish whether these effects operated directly through the effects of bonuses or through indirect effects on the evolution of other firm-level observables such as wage levels, workforce composition, and firm size. Also, since the matching estimates are based on variation in 1978 only, it is not clear whether incentives offered in later years also had negative long-run effects. To address these questions, I use a first-differenced linear regression which predicts labor productivity change as a function of firms' compensation practices and controls for concurrent changes in other firm-level observables. The basic regression specification is shown in Equation 7, where Y_{it} is log gross output per worker in 1980 prices at firm i at time t, $b_{i(t-T)}$ is the share of wages distributed on a bonus basis at time $(t-T)$, p_{it} is the share of wages distributed on a piece basis, K_{it} is log capital per worker, Z_{it} is a vector of additional firm characteristics including province- and product-specific time dummies (as well as other firm-level variables described in a footnote)[7], ν_{it} is an unobserved productivity determinant which is taken into account by planners when setting bonuses and wages, and d indicates the first-difference operator.

$$dY_{it} = \sum_{T=0}^{9} \beta_{0,T} db_{i(t-T)} + \beta_1 dp_{it} + \beta_2 dK_{it} + \delta' dZ_{it} + \nu_{it} \qquad 7$$

In Equation 7, the coefficients on the current and lagged changes in the bonus share $\{\beta_{0,T}\}_{T=0}^{9}$ measure the short- and long-run effects of bonus use on labor productivity. However, since the bonus share is correlated with the unobserved performance determinant, ν_{it}, OLS estimates of this regression are likely to yield biased coefficient estimates. Assuming that bias arises only from correlation between the ex-post bonus share and productivity, and not from correlation of a priori policies with ν_{it}, it is possible to control for endogeneity using observations of wage changes which were also regulated on a performance basis. I assume that firms' average wages are set based on planners' observations of dZ_{it} and ν_{it}, and use observed wage changes to estimate the ν_{it} seen by planners. The use of wage changes to infer ν_{it} is reasonable because SOEs followed a 'floating wage' policy during the 1980s under which provinces set quotas for wage changes based on firms' ex-post performance. A model of wage setting which reflects this is shown in Equation 8, where W_{it} is log nominal wages, γ_{jt} is a province- and time-

[7] Besides province- and product-specific time dummies, Z_{it} also includes a firm-specific dummy which absorbs a firm-level time trend, a cubic function of the firm's age, a cubic function of the firm's total employment level, the percentage of employees who are female, managerial workers, technical workers, service workers, trainees, contract workers [who in theory could have been dismissed due to negligence], and temporary workers [who were hired and dismissed relatively freely but could only be used for temporary jobs]. The omitted categories are production workers and permanent workers.

varying coefficient specifying the responsiveness of wage levels to the unobserved productivity determinant, and ε_{it} is an error term assumed to be uncorrelated with the variables in Equation 7, $db_{i(t-0)}$, p_{it}, K_{it}, and Z_{it}. The model allows wage changes to be autocorrelated for up to nine lags. This is important because a failure to control for autocorrelation could potentially bias estimates of the coefficients on lagged changes in the bonus share.

$$dW_{it} = \theta' dZ_{it} + \xi_{it} \text{ , where } \xi_{it} = \gamma_{jt}^{-1}(\nu_{it} - \varepsilon_{it} - \sum_{T=1}^{9} \phi_{jT} \xi_{i(t-T)}) \qquad 8$$

The key assumption for identification here is that the bonus share does not enter into equation 8, so that ν_{it} can be inferred without information about the bonus share. Estimation of Equation 8 by OLS yields a set of residuals, ξ_{it}, which are shown in Equation 9, where $\mu_{i(t-T)}$ represents error in the estimation of $\xi_{i(t-T)}$.

$$\xi_{it} = \gamma_{jt}^{-1}(\nu_{it} - \sum_{T=1}^{9} \phi_{jT} \xi_{i(t-T)} - \sum_{T=1}^{9} \phi_{jT} \mu_{i(t-T)} - \varepsilon_{it}) - \mu_{it} \qquad 9$$

The residuals in Equation 9 are firm-level wage changes that are orthogonal to observed workforce characteristics, province- and product type-level time effects, and firm-level time trends. I argue that these unexplained wage increases can be used to infer what provinces observe about firm productivity and thus the information used to set bonuses. Rearranging Equation 9 to solve for ν_{it}, substituting the rearranged expression into Equation 7, and redefining the error term yields the estimating equation, Equation 10.

$$dY_{it} = \sum_{T=0}^{9} \beta_{0,T} db_{i(t-T)} + \beta_1 dp_{it} + \beta_2 dK_{it} + \delta' dZ_{it} + \gamma_{jt} \xi_{it} + \sum_{T=1}^{9} \phi_T \xi_{i(t-T)} + \varepsilon_{it}$$
$$\text{where } \varepsilon_{it} = \sum_{T=1}^{9} \phi_T \mu_{i(t-T)} + \gamma_{jt} \mu_{it} + \varepsilon_{it} \qquad 10$$

I assume that the estimation errors $\{\mu_{i(t-T)}\}_{T=0}^{9}$ are uncorrelated with the observed independent variables, and thus that Equation 10 can be estimated using standard panel techniques.

I estimate several specifications of Equation 10 which show how the estimated effects of bonus use change as controls for the wage residuals are added to the model. Since Equation 10 contains a large number of variables, I report only two coefficients which summarize the short- and long-run effects of bonus use. In particular, I report the coefficient on the current period bonus share, $\beta_{0,0}$ which illustrates short-run effects and the estimated sum of the coefficients on the lagged bonus share, $\beta_{0,1}$ + … + $\beta_{0,9}$, which illustrates long-run effects. For one specification, I also graph the point estimates for each coefficient on the bonus share as well as the point estimates of the coefficients on the current and lagged wage residuals, γ_{jt} and $\{\phi_{0,T}\}_{T=0}^{9}$. To provide a summary measure of the overall effects of bonuses, I calculate the estimated average effect of current and past bonus use on log labor productivity in 1988. I calculate this effect by weighting the sum of all of the coefficients on the bonus share by the sample means of the current (1988) and lagged (1978-1987) bonus shares.

Estimations of Equation 10, shown in Table 1, indicate that bonus use improved current period labor productivity, but had negative effects on future productivity. In Specification (1), I omit the current and lagged residuals, $\{\xi_{i(t-T)}\}_{T=0}^{9}$, which control for endogenous bonus setting. I also omit controls for the capital-labor ratio, which is observed for only a minority of firms and thus reduces the ability to control for other covariates when included. Since bonus distributions are in part responses to increases in productivity, this specification should overestimate the positive effects of bonuses. Nevertheless, the results do not provide support for an overall positive effect of bonuses. While the estimated short-run effects are positive, the estimated long-run effects are negative and slightly larger in magnitude. The estimated overall effect on labor productivity as of 1988 is approximately zero. Specification (2) is identical to Specification (1) except that it incorporates controls for current period residuals, ξ_{it}. For the time being, I assume that the responsiveness of average wages to the productivity determinant, ν_{it}, is constant across provinces and over time and thus impose the constraint that (γ_{jt}=γ). Adding in the current period wage residuals reduces the estimated positive effects of bonus use by about 60 percent and increases the estimated negative effects by about 30 percent. As a result, the estimated overall effect of bonuses on labor productivity in 1988 is now negative and equal to -0.16 log points.

In Specification (3), I control for serial correlation in the wage setting process by adding both current and lagged wage residuals, $\{\xi_{i(t-T)}\}_{T=0}^{9}$, to the regression, while continuing to impose the constraint that the responsiveness of average wages to ν_{it} is constant over time and across provinces. If serial correlation in wage setting is present in the data, but not controlled for in the estimation procedure, this will result in correlation between the lagged bonus share and the error term. However, the coefficient estimates in Specification (3) are almost identical to those in Specification (2), suggesting that serial correlation between lagged wage changes and lagged bonus offerings is not a significant issue.

Since the residuals, $\{\xi_{i(t-T)}\}_{T=0}^{9}$, are changes in wages, Specification (3) can also be interpreted as comparing the persistence of productivity changes associated with increases in bonus use with those associated with wage increases. To illustrate this, I graph estimates of the coefficients on changes in the bonus share in Specification (3), together with 95 percent confidence intervals for these estimates in Figure 4. The point estimates show that bonus use in the current year and in the most recent year had positive effects on current labor productivity, but that bonus use in all prior periods had negative effects. These negative effects become larger for longer lags, suggesting that distortions induced by bonuses were most severe for activities which took many years (five or more) to affect productivity. For comparison, I also graph the point estimates of the coefficients on the wage residuals in Figure 5. Figure 5 shows that current period wage changes were tightly correlated with changes in current labor productivity, but that past wage changes were not correlated with changes in current labor productivity. This indicates that, unlike labor productivity increases associated with increased reliance on bonuses, labor productivity increases associated with increases in the firm-level wages persisted over time.

In Specification (4), I repeat Specification (3), but allow the responsiveness of wage changes to ν_{it} to vary arbitrarily over time and across provinces. Given the significant changes in the compensation system that occurred during the 1980s and probable variation in how and when these changes were instituted across provinces, variation in responsiveness seems quite likely. However, since the estimated effects of bonuses in this regression are extremely similar to those in Specification (3), this cross-province variation does not appear to have been related to how bonus use affected firm performance. This is important because it supports the claim that the observed correlation between changes in productivity and current and past bonus use were due to the bonus system itself, rather than correlation between the use of bonuses and other unobserved changes in the compensation system.

All of the specifications so far have omitted data on differences in capital intensity across firms, which could be problematic if bonus use is correlated with investment. Raw correlations in the data suggest this was the case, with firms offering larger bonuses also investing more, perhaps because firm performance was judged in part by firms' success in meeting investment targets. Data on capital intensity is only available for about one-fifth of the total number of observations and inclusion of this data reduces the ability to control for other variables. In Specifications (5) and (6), I restrict the sample to observations where capital intensity is observed and, to accommodate the reduced sample size, I replace province- and product variety-specific time dummies with a set of time dummies common to all firms and also drop firm-specific time trends from the regression. As in Specification (3), I include controls for the current and lagged wage residuals but constrain the responsiveness of wages to be constant across provinces and over time. Specifications (5) and (6) are identical, except that Specification (5) controls for the log capital-labor ratio, whereas Specification (6) omits this control. Since estimates of the effects of bonuses in Specifications (5) and (6) are extremely similar to each other, and qualitatively similar to estimates in Specifications (2) and (3), effects on capital intensity do not appear to have played a significant role in the short- and long-run effects of bonus use.

Even when wage residuals are included in the regression, there could still be concerns about whether the variation in the bonus share is endogenous to other unobserved firm-level characteristics that affect productivity. To address this, I use an instrumental variables technique which isolates variation in compensation policy across provinces as a source of identification. Province-level differences in bonus use likely reflected debate among provincial administrations over compensation policy rather than intrinsic firm characteristics. The instrumental variables regression is based on testing whether the adoption of bonuses had more pronounced effects on productivity in provinces where firms distributed larger amounts of bonuses on average.

The regression specification is shown in Equation 11, where Z_{it} is the same as in previous regressions except that it omits province-specific time dummies and firm-specific time trends, J(i) denotes the set of all firms located in the same province as firm i, $J(i)^{-i}$ denotes this set after the exclusion of firm i itself, $W_{J(i)^{-i}(t-T)}$ denotes the mean log wage among firms in the set $J(i)^{-i}$ at time *(t-T)*, and ε_{it} is an additive error term.

$$dY_{it} = \sum_{T=0}^{9} \beta_{0,T} db_{i(t-T)} + \beta_1 dp_{it} + \sum_{T=0}^{9} \beta_{2,T} dW_{J(i)^{-i}(t-T)} + \delta' dZ_{it} + \varepsilon_{it} \qquad 11$$

One concern with the use of province-level bonus measures as instruments is that they could reflect province-level productivity shocks rather than policy differences. To correct for this I have incorporated provincial average wages in Equation 11 as a control for province-level productivity shocks. I assume that after inclusion of this control the error term in Equation 11, ε_{it}, is not correlated with the bonus and piece-rate shares of other firms in same province. This assumption is shown in Equation 12, where $j \in J(i)^{-I}$ denotes a firm *j* in the set of firms in the same province as firm *i.*

$$E[db_{j(t-T)}\varepsilon_{it}] = E[dp_{jt}\varepsilon_{it}] = 0 \text{ for all } i,t,T \text{ and } j \in J(i)^{-i} \qquad 12$$

Under this assumption, $db_{j(t-T)}$ and dp_{jt} provide valid instruments for $db_{i(t-T)}$ and dp_{it}. However, these instruments are also highly correlated over time and do not by themselves provide enough information to identify Equation 11. To provide better identification, I supplement these variables with dummies for bonus and piece-rate use. This allows firms which have not yet adopted bonuses and piece-rates in each province to serve as a control group which should not be affected by provincial bonus policy. Within-province differences in performance trends between the group of firms using bonuses in any given year and firms in the control group provide the main source of identification here. Additional identification comes from differences in productivity trends across provinces which used bonuses to different degrees. As a first step to creating the instruments, I define a dummy for piece-rate use, I^p_{jt}, which is equal to 1 if a strictly positive piece-rate is offered and equal to 0 otherwise, and as shown in Equation 13, I assume that the adoption of piece-rates is exogenous and thus uncorrelated with the error term.

$$E[I^p_{i(t-T)}\varepsilon_{it}] = 0 \text{ for all } i,t,T \qquad 13$$

Since bonus issues reflect ex-post observations of performance, the assumption that bonus adoption is not correlated with current performance is much less plausible. Accordingly, I do not make the assumption that an analogous dummy for bonus use, I^b_{it}, is uncorrelated with the error term. Instead, I control for current and lagged changes in I^b_{it} in the regression using a series of flexible functions of I^b_{it}, which I denote $v_t(\{dI^b_{i(t-T)}\}^9_{T=0})$. The modified regression, which is shown in Equation 14, tests whether the effects of bonus adoptions are related to the size of the bonus offered or are independent of them.

$$dY_{it} = \sum_{T=0}^{9} \beta_{0,T} db_{i(t-T)} + \beta_1 dp_{it} + \sum_{T=0}^{9} \beta_{2,T} dW_{J(i)^{-i}(t-T)} + \delta' dZ_{it} + v_t(\{dI^b_{i(t-T)}\}^9_{T=0}) + \varepsilon_{it} \qquad 14$$

To demonstrate robustness, I experiment with several linear specifications of $v_t(\{dI^b_{i(t-T)}\}^9_{T=0})$ and show that the results are qualitatively similar regardless of how $v_t(\{dI^b_{i(t-T)}\}^9_{T=0})$ is constructed, though the estimated magnitude of the effects does vary considerably.

I measure bonus and piece rate policies using the average bonus and piece-rate shares of firms offering bonuses and/or piece-rates in each province, and excluding the firm under observation to avoid spurious correlation. The two policy measures, b^{-i}_{Jt} and p^{-i}_{Jt}, are defined in Equations 15 and 16.

$$b_{J(i)t}^{-i} = \frac{1}{\sum_{j \in J(i)^{-i}} I_{jt}^{b}} \sum_{j \in J(i)^{-i}} I_{jt}^{b} b_{jt} \qquad 15$$

$$p_{J(i)t}^{-i} = \frac{1}{\sum_{j \in J(i)^{-i}} I_{jt}^{p}} \sum_{j \in J(i)^{-i}} I_{jt}^{p} p_{jt} \qquad 16$$

To instrument for the bonus and piece-rate shares, I interact the policy measures, b_{Jt}^{-i} and p_{Jt}^{-i}, with current and lagged dummies for bonus and piece rate use, $I_{i(t-T)}^{b}$ and $I_{i(t-T)}^{p}$. The exclusion restriction is that interactions between I_{it}^{b} and the mean bonus and piece-rate shares in each province do not enter into the function $v_t(\{dI_{i(t-T)}^{b}\}_{T=0}^{9})$. The full set of instruments, X_{it}, is shown in Equation 17.

$$X_{it} = \{\{d(I_{it}^{b} b_{Jt}^{-i})\}_{T=0}^{10}, \{d(I_{it}^{b} I_{it}^{p} b_{Jt}^{-i})\}_{T=0}^{10}, d(I_{it}^{b} p_{Jt}^{-i}), d(I_{it}^{p} I_{it}^{b} p_{Jt}^{-i})\} \qquad 17$$

Estimations of Equation 14 using the instrument set, X_{it}, provide evidence that increased reliance on bonuses was associated with increased short-run labor productivity and decreased long-run labor productivity. To start with, I estimate the equation without including any controls for the endogeneity of bonus adoptions. Since bonus adoptions are likely related to productivity improvements, this specification may bias the estimated positive effects of bonus use upwards. In Table 2, I compare OLS estimates of this equation, Specification (1), to the instrumental variables estimates, Specification (2). Both specifications indicate positive short-run effects of bonuses as well as larger, negative long-run effects. The coefficient estimates differ in the two specifications— the IV results give larger positive short-run effects—but the difference does not alter the qualitative finding that bonus use was detrimental to labor productivity growth in the long-run.

Results from Specifications (1) and (2) will be biased if transitions between zero bonus use and positive bonus use are influenced by productivity. To correct for productivity-dependent transitions, I use a set of current and lagged adoption dummies to remove any dynamic effects that are constant over time and across provinces, as shown in Equation 18.

$$dY_{it} = \sum_{T=0}^{9} \beta_{0,T} db_{i(t-T)} + \beta_1 dp_{it} + \sum_{T=0}^{9} \beta_{2,T} dW_{J(i)^{-i}(t-T)} + \delta' dZ_{it} + \sum_{T=0}^{9} \xi_{0,T} dI_{i(t-T)}^{b} + \varepsilon_{it} \qquad 18$$

The results from estimation of Equation 18, shown in Specification (3), indicate substantially larger negative long-run effects than those estimated in Specification (2). This suggests that endogenous bonus adoptions may be biasing the estimated effects of bonuses upwards.

Since bonus policy changed rapidly during the late 1970s and 1980s, the effects of adoptions could have varied over time. The size of bonuses increased over time and the coefficients on the bonus share could be capture time-varying effects that are correlated with this increase in bonus size. To test whether this is occurring, I estimate an additional specification which allows the effects of current and lagged bonus adoptions to vary freely for each year from 1978 to 1988. The new specification is shown in Equation 19, where t_t is a set of time dummies for each year between 1978 and 1988.

$$dY_{it} = \sum_{T=0}^{9} \beta_{0,T} db_{i(t-T)} + \beta_1 dp_{it} + \sum_{T=0}^{9} \beta_{2,T} dW_{J(i)^{-i}(t-T)} + \delta' dZ_{it} + t_t \sum_{T=0}^{9} \xi_{0,T}^{t} dI_{i(t-T)}^{b} + \varepsilon_{it} \qquad 19$$

The results from estimating Equation 19, shown in Specification (4), are extremely similar to those in Specification (3). The lack of movement in the coefficients suggests that variation in the effects of bonus adoption is due to changes in the bonus share, and not other concurrent and unobserved changes in compensation systems.

Another potential concern is that variation in bonus levels across provinces—the key source of identification in these instrumental variables regressions—are correlated with other provincial characteristics and that variation in these characteristics could be responsible for the varying effects of bonus adoptions. To address this, I control for interactions between bonus adoptions dummies and two relevant provincial characteristics, the average wage level and the fraction of firms offering bonuses in in each province. The wage level is a control for heterogeneous effects that are correlated with provincial wage levels. This could be important if bonus adopting firms in high productivity provinces have attained a maximum feasible level of productivity and bonus-using firms in lower wage provinces, which also offer lower bonuses on average, are catching up with them. Control for the fraction of firms using bonuses in each province is based on the idea that the information which a bonus adoption conveys about a firm's productivity may vary depending on how common bonus use in its environment. The regression specification is shown in Equation 20, where $f_{J(i)(t-T)}$ is the bonus fraction at time *t-T* in the province where firm i is located.

$$\begin{aligned} dY_{it} &= \sum_{T=0}^{9} \beta_{0,T} db_{i(t-T)} + \beta_1 dp_{it} + \sum_{T=0}^{9} \beta_{2,T} dW_{J(i)^{-i}(t-T)} + \delta' dZ_{it} + \\ &\sum_{T=0}^{9} \left(\xi_{0,T} dI_{i(t-T)}^{b} + \xi_{1,T} d(I_{i(t-T)}^{b} W_{J(i)^{-i}(t-T)}) + \xi_{2,T} d(I_{i(t-T)}^{b} f_{J(i)(t-T)}) + \xi_{3,T} df_{J(i)(t-T)} \right) + \varepsilon_{it} \end{aligned} \qquad 20$$

The results from estimating Equation 20, which are presented in Specification (5), suggest that variation in these provincial characteristics cannot explain the observed effects of bonuses on firm performance. Coefficient estimates in Specification (5) are qualitatively similar to those in Specification (3), which assumed that adoption effects were constant across provinces, but the estimated negative long-run effects are significantly larger in Specification (5).

In general the instrumental variables estimates imply that bonus use had effects of significantly larger magnitude than is suggested by the first-differenced panel results and are much more variable across specifications. I see no obvious reason for preferring either one of the two approaches, but base the subsequent analysis on the first-differenced panel results because they yield more conservative estimates of the magnitude of the effects.

To elucidate how the effects of bonuses varied over time, I use results from specification (3) in Table 1 to estimate the impact of expanded bonus distributions on labor productivity in each year from 1978 to 1988. In Figure 6, I depict changes in the mean bonus share over time, together with estimates of their impact on log labor productivity. Effects are measured relative to the counterfactual that the bonus share remained fixed at its 1977 level. The figure indicates that increases in bonus distributions had a modest positive impact on labor productivity during the late 1970s and early 1980s, and a large negative impact during the late 1980s. Though I lack quantitative data to verify whether the prediction is accurate, the regressions predict that the negative effect of bonuses on labor productivity trends would continue to strengthen through the early 1990s. Enterprise case studies suggest that iron and steel SOEs did suffer deteriorations in performance during the early 1990s, and Steinfeld (1998) attributes these at least in part to their pursuit of myopic management strategies during the 1980s. He argues that firms rapidly expanded in production capacity in market segments where there was no long-run demand because this strategy generated the appearance of success in the short-run.

The estimated dynamic effects of bonuses are consistent with the view that bonuses adversely impacted social welfare, but provided private benefits for enterprise insiders. From the perspective of a social planner in 1978 who discounted the future at a rate of 0.9, the average predicted effect of bonuses issued between 1978 and 1988 would be equivalent to a reduction in current labor productivity of -0.65 log points, or the loss of about fifty percent of one year's output.[8] From the perspective of an enterprise manager, on the other hand, one's high likelihood of separating from the firm would lead to a more positive assessment of bonuses. According to Liu and Otsuka (2004), the average tenure among iron and steel SOE managers was about 4.5 years in 1995, corresponding to about a 22 percent probability of turnover per year.[9] Assuming that managers had a constant probability of job separation, placed value only on events occurring within their tenure, and shared the same discount rate as planners, the predicted effects from their perspective would be equivalent to an increase in current period labor productivity of 0.02 log points.[10] If managers instead served fixed terms of a predictable five-year duration and thus placed no weight on productivity changes occurring after five years, their valuation would be considerably higher at 0.06 log points. This indicates that managers could have perceived the use of bonuses as personally beneficial, even if they were fully aware of their impact on future performance. Since workers were essentially tied to their jobs until retirement, a performance decline would not have been beneficial to them ex-post. However, workers in the late 1970s and early 1980s probably doubted that incentive policy would endure for decades. Incentives introduced in the mid-1950s and mid-1960s were revoked in subsequent years (refer to Figure 1). If workers expected the 1980s incentive policy to suffer a similar fate, then it would have made sense for them to behave myopically.

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[8] I calculate the present value of all labor productivity changes resulting from bonuses distributed between 1978 and 1988 as $\Delta Y_{PV} = \sum_{t=1978}^{1988} \delta^{t-1978} \Delta_{PV,t}$, where $\Delta_{PV,t} = \sum_{T=0}^{10} \delta^{T} \bar{b}_t \beta_{1,T}$ is the present value of labor productivity changes resulting from bonuses distributed in period t evaluated at time t, $\beta_{1,T}$ is the coefficient on the T-period lag of the bonus share, $\overline{b_t}$ is the mean bonus share in period t, and δ is the discount factor.

[9] Otsuka and Liu (2004) give the average tenure of managers of state enterprises as 5.2 years, and that of managers of township and village enterprises as 3.7 years. The sample I use includes both types of government enterprise and does not clearly distinguish between them, so I use the simple average of these two numbers.

[10] To calculate the manager's private valuation, I replace the discount factor, δ, with the product of the discount factor and unity minus the manager's probability of separation, δ(1-0.22).

Conclusion

This paper has shown that reform of the bonus system between 1978 and 1988 had a severely negative impact on SOE labor productivity in the Chinese iron and steel industry. Unlike most empirical studies of incentives, I explicitly contrast short- and long-run effects. Here, the contrast between the short- and long-run is highly revealing, as the effects differ radically in both direction and magnitude. To avoid misleading results, researchers should attempt to differentiate between short- and long-run effects in studies of incentives. The potential for these effects to move in opposite directions may be one reason why time wages are more common than performance-based payments in market economies.

The key policy implication of these findings is that the decision to apply incentives, whether in the public sector or in private firms, should be informed by an estimate of their long-run effects. Proponents of incentive payments often argue that they align the interests of principals and agents and thus promote more efficient decision-making. In the Chinese iron and steel industry, incentives had the opposite effect, encouraging managers to pursue value-destroying strategies. In practice, this effect would have been difficult to anticipate a priori. Policy makers, observing initial performance gains, probably expected these effects to continue as incentives were strengthened, and this may have encouraged nationwide adoption of incentive use. In developed market economies, owners tend to have superior means of monitoring managers, but they still face the problem of distinguishing increases in current performance from changes in firm value. Excessive short-run incentives in the American financial sector have been identified as a key contributor to the current banking crisis (Cheng, Hong, and Scheinkman 2009). The difficulty in distinguishing current period from long-run effects probably played a role in the diffusion of these incentive practices.

From the perspective of Chinese economic history, the key contribution of this paper is to place the shift in trend performance of state-owned industry in the mid to late 1970s in context by comparing it to earlier changes in trends. Several studies have attempted to demonstrate the effects of market-based reform on state-owned industry by comparing productivity trends prior to 1978 to those afterwards, giving the pre-1978 period only cursory treatment. Explicit examination of detailed pre-1978 data suggests the link between market reform and growth in state industry be treated with more skepticism. Radical breaks in performance trends occurred prior to 1978, and they seem to be more closely associated with political disorder and accompanying policy changes than with the use of incentives. Until these prior trend breaks are understood and differentiated from the trend shift in the late 1970s, researchers should be wary of vesting institutional changes unique to the 1980s with excessive significance.

Figure 1: Aggregate Data on Labor Productivity and Incentive Use in the Iron and Steel Industry

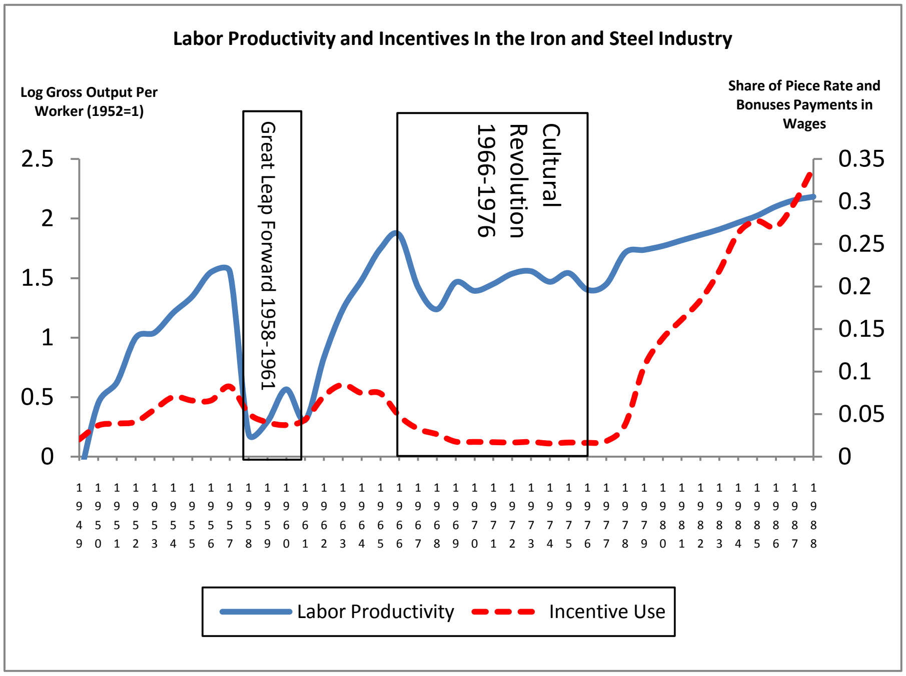

Figure 1 shows long-run changes in labor productivity and incentive use in the Chinese iron and steel industry. Periods of rising labor productivity tend to coincide with rises in incentive use. However, this correlation may be an artifact of correlation with major political movements. The 'leftist' political faction which controlled economic policy during the Great Leap Forward and the Cultural Revolution rejected the use of material incentives. However, there could be other more important causes for poor performance during these periods. Besides their objection to incentives, the 'leftist' faction also rejected the use of education and ability as wage-setting criteria, ceased imports of foreign capital goods, and prioritized employment growth over productivity. All of these changes probably had a negative impact on labor productivity during the Great Leap Forward and the Cultural Revolution. In the post-Cultural Revolution period, it is not clear whether the rising trend in labor productivity is related to the expanded use of incentives or policy improvements in other areas.

Figure 2: Effect of Incentive Adoption in 1978 on Bonus Use

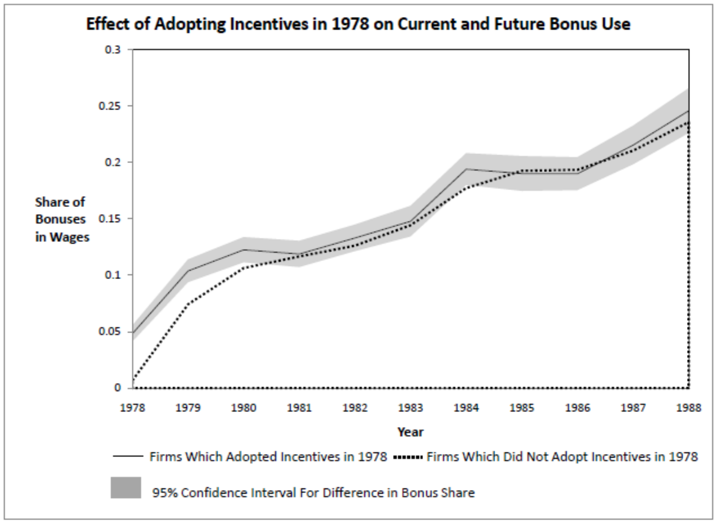

Figure 2 shows the effect of early adoption of incentives on the bonus share in each year from 1978 to 1988. The figure shows that participating firms had significantly higher levels of bonus use from 1978 to 1980, but that their bonus levels converged to levels similar to those of the non-participating firms in the ensuing years. In the figure, I compute the average bonus share for the non-participating group as the mean bonus share in the entire sample after subtracting out the estimated treatment effect for the participating group. The bonus share for the participating group is calculated as the average bonus share for the non-participating group (as shown in the figure) plus the estimated treatment effect associated with participation. The shaded region around the participating group's bonus share depicts a 95% confidence interval for the estimated treatment effect.

Figure 3: Effect of Incentive Adoption in 1978 on Labor Productivity Growth

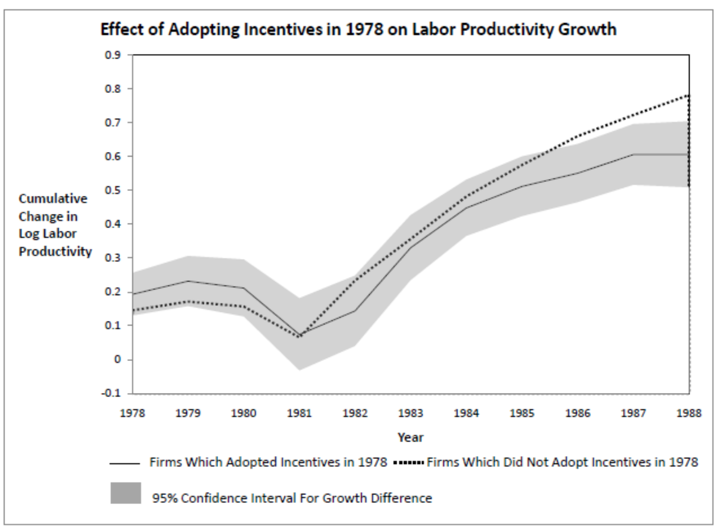

Figure 3 shows results from a matching estimator comparing labor productivity change in firms which participated in incentive adoption in 1978 to those which did not. The figure shows that participating firms had more rapid productivity growth during the initial three years of policy implementation (1978 to 1980), but inferior labor productivity growth in the long-run (1982 to 1988). The cross-group differences in the final three years (1986 to 1988) are statistically significant at the 5 percent level and large in magnitude; for example the estimated effect in 1988 is a 17% loss in cumulative growth in log labor productivity. I compute cumulative labor productivity growth for each firm as the difference in log gross output per worker in the year on the x-axis and the firm's 1977 labor productivity level. Gross output is measured in constant 1980 prices. Average labor productivity growth for the non-participating group is calculated as average labor productivity change in the entire sample after subtracting out the estimated treatment effect for the participating group. Average labor productivity change for the participating group is calculated as average labor productivity growth for the non-participating group plus the estimated treatment effect. The shaded region around the participating group's labor productivity change depicts a 95% confidence interval for the estimated treatment effect.

Figure 4: Point Estimates of Coefficients on the Bonus Share

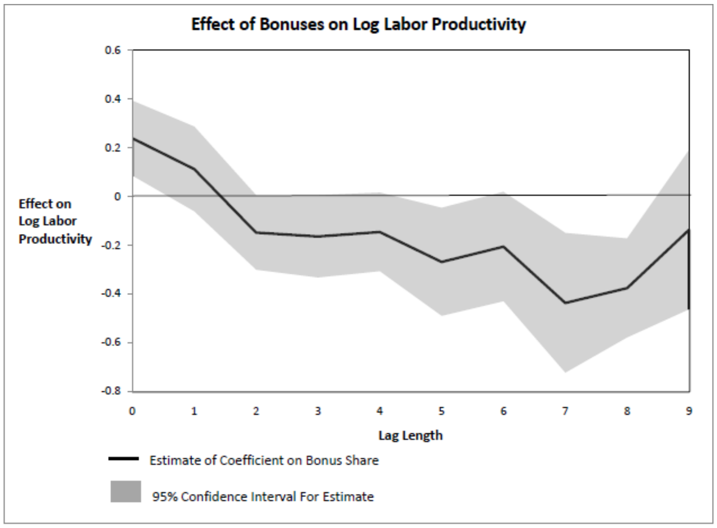

Figure 4 shows the coefficients on the current and lagged bonus share estimated in Table 1, specification 3. The solid line shows the coefficient estimates themselves and the shaded region bounds a 95 percent confidence interval around the point estimates. The positive coefficients on the current period coefficient and the first period lag indicate that bonus use had a positive effect on current labor productivity. The negative coefficients on the second through ninth period lags indicate that bonus use had a negative effect on future labor productivity.

Figure 5: Point Estimates of Coefficients on Wage Residuals

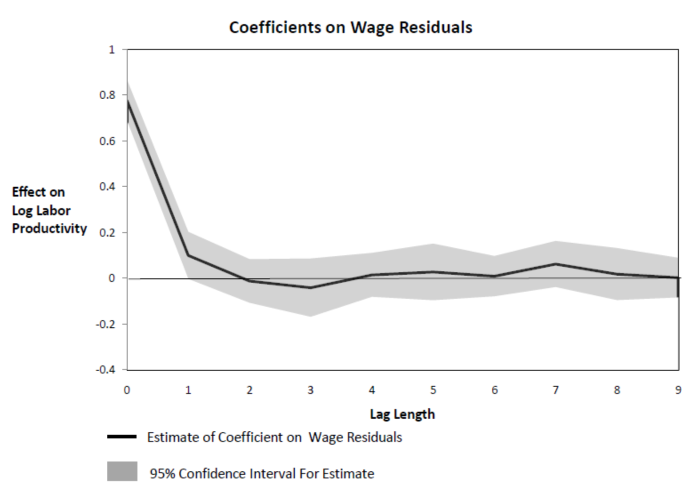

Figure 5 shows the coefficients on the current and lagged changes in wage residuals estimated in Table 1, specification 3. The solid line shows the coefficient estimates themselves and the shaded region bounds a 95 percent confidence interval around the point estimates. The positive coefficients on the current period and first period lag of the wage residuals indicate that wage increases were correlated with increases in current labor productivity. Coefficients on the second through ninth period lags are near zero indicating that past wage increases were not correlated with changes in current labor productivity.

Figure 6: Estimated Effect of The Expansion of Bonus Payments on Labor Productivity

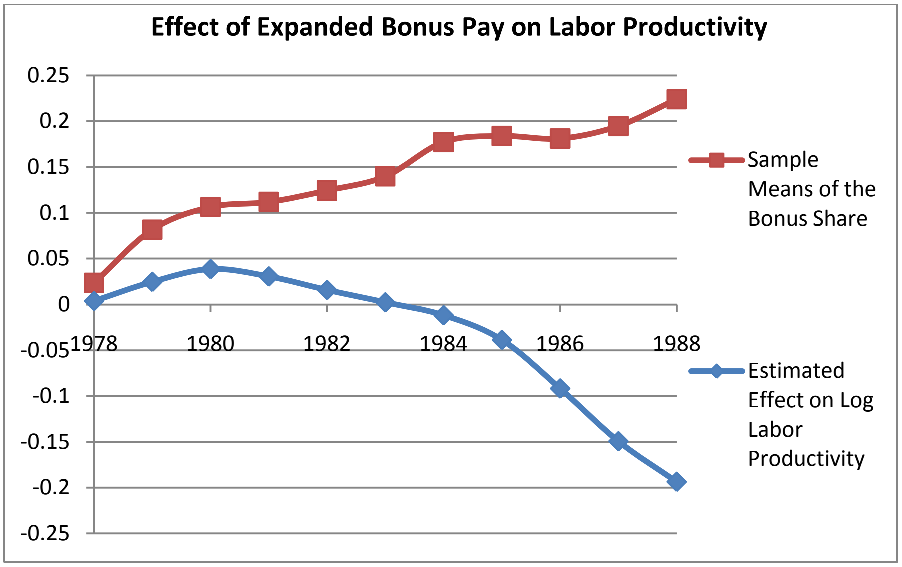

Figure 6 shows the sample mean of the bonus share in each year from 1978 to 1988 together with the estimated dynamic effect of these increases on labor productivity. I use the coefficients estimated in Specification 3 in Table 1 to estimate the dynamic effect on productivity. The calculation is relative to the counterfactual that bonuses had remained fixed at their 1977 level throughout the decade. The figure indicates that bonus distributions had a modest positive impact on labor productivity during the late 1970s and early 1980s, and a large negative impact during the late 1980s. The time course of effects is similar to the matching estimates depicted in Figure 3. As in Figure 3, effects are positive prior to 1983, and negative afterwards.

Table 1: First-Difference Estimates

Independent Variables	First Difference OLS (1)	Current Wage Residuals (2)	Current and Lagged Wage Residuals (3)	Current and Lagged Wage Residuals; Province- and Time-Specific Wage Effects (4)	Capital Intensity Control (5)	Restricted Sample: Omitting Capital Intensity Control (6)
	Dependent Variable (Log Gross Output Per Worker) in 1976-1988					
b_{it}	0.7*** (0.1)	0.3*** (0.1)	0.2*** (0.1)	0.2** (0.1)	0.3* (0.2)	0.3* (0.2)
$\sum_{T=1}^{9} db_{i(t-T)}$	-1.3** (0.7)	-1.7** (0.7)	-1.8*** (0.7)	-1.9** (0.8)	-2.2*** (0.8)	-2.3*** (0.8)
Implied Cumulative Effect on 1988 Log Output Per Worker	-0.01 (0.10)	-0.16* (0.10)	-0.17* (0.10)	-0.19* (0.11)	-0.21 (0.13)	-0.21 (0.13)
Includes Current Wage Residual	No	Yes	Yes	Yes, Province- and Time-Specific Coefficients	Yes	Yes
Includes Lagged Wage Residuals	No	No	Yes	Yes	Yes	Yes
Includes Capital-Labor Ratio	No	No	No	No	Yes	No
Includes Firm Specific Time Trend	Yes	Yes	Yes	Yes	No	No
Time Dummies	Variety and Province	Variety and Province	Variety and Province	Variety and Province	National	National
N	7603	7603	7603	7603	1494	1494

Standard errors, reported in parentheses, are clustered at the province level.
***1% significance **5% significance *10% significance

Table 2: IV Estimates

		Dependent Variable (Log Gross Output Per Worker) in 1976-1988				
Independent Variables	First-Difference OLS (1)	IV with Exogenous Adoptions (2)	IV with Endogenous Adoptions (3)	IV with Endogenous Adoptions (4)	IV with Endogenous Adoptions (5)
b_{it}	0.6*** (0.1)	1.1*** (0.3)	0.9** (0.5)	0.9* (0.5)	0.8 (0.5)
$\sum_{T=1}^{9} db_{i(t-T)}$	-2.2*** (0.6)	-2.5** (1.1)	-3.9*** (1.5)	-3.7** (1.7)	-4.5** (1.9)
Implied Cumulative Effect on 1988 Log Output Per Worker	-0.15* (0.09)	-0.10 (0.19)	-0.33* (0.20)	-0.29 (0.24)	-0.45* (0.25)
Current and Lagged Adoption Dummies	No	No	Yes	Yes; Time-Specific	Yes
Interaction between Adoption Dummies and Fraction Adoptions and Provincial Wage Level	No	No	No	No	Yes
Underidentification Test (p-value)	N/A	0.0001	0.0001	0.03	0.0001
Overidentification Test (p-value)	N/A	0.58	0.44	0.27	0.28
N	4049	4049	4049	4049	4049

Standard errors, reported in parentheses, are clustered at the province-product type level. Province-level clusters are infeasible because the number of instruments (22) would exceed the number of provinces for which instruments can be calculated (16).
***1% significance **5% significance *10% significance

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