Coal Mine Safety and Coal Yield: A First Look

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Abstract: This paper analyzes and tests relationship between coal mine mortality and coal yield in China. It proposes a theory illustrating that yield can be either positive or negative related to mortality, depending on three effects: demand effect, type I (firm) and type II (industry) supply effect. Using a cross-region panel-data fix-effect model and introducing IVs, it identifies those three effects. The result shows that type I supply effect plays a more significantly role than the other two, thus explains the puzzling negative mortality-yield relationship. It implies that "cutback and shutdown" government policy may have adverse effect on mortality, while capacity building by large state-owned enterprises and others can keep it within limits.

Keywords: coal mine safety, coal yield, panel data fix effect, instrumental variables

JEL Classification: J28, Q41

I. Introduction

In year 2005, 5,938 persons died in China's coal production; the number ranked second among all sorts of job deaths officially listed. (*China Coal Industry Yearbook,* 2005; State Administration of Work Safety (SAWS), 2006) [1]. Eyes of the public have been caught year after year by such bloody facts[2] that emotionally charged and extremely stated opinions prevailed[3]. However, a considerate view will believe that China's economic growth begin to face its weakness, and "mine disasters" just one of costs must be paid for its power. By this view, we can only hope life is saved when such a fantastic growth is sacrificed.

However, this argument faces challenges from facts. Coal yield rose rapidly indeed recently, but NOT the deaths, and not surprisingly, the mortality, deaths per unit of coal produced, even decreased. More generally, at least in recent decade, deaths always went down when yield was up, and vice versa. This negative relationship is shown in figure 1, which depicts coal industry deaths and coal yield from 1994 to 2005 in China. In particular, macroeconomic expansion since 2000 pushed yield to an unprecedented level, while the deaths *decreased* significantly.

Someone may contribute the puzzling (at least in a first look) phenomenon to governments' safety policy, or firms' safety input, which is so powerful that reverses the would-be positive relationship between yield and mortality. However, there are several problems about this optimistic view: First, government interventions on work safety have been steadily increased for more than a decade, but we do not see steadily decreased deaths at the same time; in fact, they increased in years not far away. Second, as we perceived, policy means has been focusing on quantity control (quotas). If it worked, decease in yield should have been found as well as in death numbers, which would remain a positive relationship between them. Thirdly, as a matter of fact, news report does not convince us that firms or governments have increased safety inputs quite enough[4]. Finally, in a general view, safety input or policy should influence the long-term trend

[1] Road transportation accident ranked No.1, with an amount 20 times as coal mine accidents.

[2] There are a huge number of media reports on China's coal mine safety. One of the most influential is a cover story and year-topic article on *Caijing* Magazine, "Exploring the Source of Mine Disasters" (Caijing, 2004). For western media reports, see, for example, The Economist (2002, 2004).

[3] A word from a person-in-charge of the SAWS is widespread: "Coal with blood should always be abandoned."(Caijing, 2004)

[4] Li Yi-zhong, director general of the SAWS, said recently, "One of the reasons for the mine disasters is that our

rather than the short-term fluctuation of yield and safety, as we see here.

(Figure 1)

This paper launches to give a consistent and systematic explanation, both theoretically and empirically, on relationships between coal yield and mortality, and through it, identifies forces affecting the market. By using supply and demand analysis, we illustrate that there can be positive or negative relationship between yield and mortality. Three effects are picked up: demand effect, which affects demand in the coal market; type I supply effect, which affects the number of firms in the market but not a typical firm's supply; type II supply effect, which affects a typical firm's supply (and mortality) but not the number of firms in the market. We will see that, demand effect results in a positive relationship between yield and mortality, and type I supply effect results in a negative relationship between them. Type II supply effect has ambiguous results, depending on specific factors under consideration. If type I supply effect dominates, a negative relationship between yield and mortality can be observed.

Based on the theory we proposed, a simultaneous equation model has been raised but then reduced into an estimable single equation containing the observables. By using coal yield of the state-owned major enterprises (SMEs) as an instrumental variable (IV), we identify those three effects. The empirical results, using provincial panel data, show that, type I supply effect plays a more significant role than other effects.

This research has important policy implications. It illustrates that, more diversified factors affect safety outcomes in coal industry than we imagine. Particularly and unexpectedly, a "cutback and shutdown" policy probably has adverse effect, and capacity building by the SMEs and other firms in recent years can be helpful to mine safety.

This research is related to two kinds of literature. One group of literature has the same issues, but different mechanisms. Ruser and Smith (1991) and other researches testified that, the OSHA (Occupational Safety and Health Administration) regulations in the U.S. had almost no effects on safety improvements in the workplace. But they did not explain why the policy failed. Our research has pointed out that government safety regulations might change firms' safe behavior through market forces. The other group of literature raises different issues, but illustrates the similar mechanism. Brown and Silverman (1973) showed that governments' drug interdiction increased rather than decreased drug-related crimes. However, their research emphasizes market influences on the demanders, but ours on the suppliers (coal mines).

In section 2 we build our theory to illustrate relationships between coal yield and mortality. Section 3 and 4 do empirical justifications. In section 3, we conduct a Granger test using the national level time-series, to preliminarily explore the *direction* of causalities between mortality and yield. Section 4 is the main body of our empirical study. There we use the provincial panel data fixed-effect model with and without instrumental variables, to identify three effects through which coal yield influences mortality. We also do endogeneity test on coal yield and other robust checks in this section. The final section is for conclusions and implications.

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mines have not paid enough for safety issues for a long time. The debt is large." Until 2005, such a "debt" was amounted to around RMB 50 billion yuan. In that year, a safety fund of 3 billion yuan, financed by national debt, was announced to be put into use (Caijing, 2005).

II. Theoretical Framework and Empirical Strategy

Our theoretical framework consists of two building blocks: one is firm behavior, which illustrates the relationship between mortality and yield in *a single firm*; the other is market mechanism, which illustrates the relationship between mortality and yield in *the whole market*.

1. Firm Behavior

We propose a simple model to analyze a single firm's behavior (For reference, see Borjas, 2000, chapter 6). A firm tries to maximize its profits but must guarantee workers their reservation utilities. Workers' reservation utility positively relies on wages and negatively relies on mortality. The firm's profit negatively relies on wages it pays to workers, but positively on mortality, since a higher mortality implies a lower safe expenditure. Besides, for simplicity, we assume the firm's yield depends only on the number of workers, with constant returns to scale. And its safe expenditure is a private good, i.e., it works only to the worker it aims to; others can not free ride. It rules out possible scale effects from safe expenditures.

A single firm's yield should be positively related to its mortality: As yield increases, mortality also increases. Let's explain why. As yield increases in a given period, more workers work (or, in reality, given workers work longer) in the coal well, thus excavate more intensively the mineral deposit. This usually makes working environments more danger[5]. Realizing this, the firm and workers will reach an agreement, resulting in a riskier working environment as well as a higher wage. Figure 2 illustrates this reasoning. The horizontal axis represents the mortality (measuring job risks); the vertical axis the wage level. The upward U_0 curve represents the indifference curve of a worker's reservation utility. The downward π curves are firm's iso-profit curves, with π_l and π_h representing profits when the firm has a low and a high yield. As we mentioned, an increase in yield makes the work riskier. Or, from the firm's view, it becomes more costly to improve the safety level at the margin, resulting in deeper iso-profit curves. Suppose workers have no bargaining power thus always get reservation utilities, then we can easily see that, in equilibrium (tangency points of two kinds of curves), mortality increases with yield.

Interestingly, although we assume constant returns to scale, we still have an increasing marginal cost, or an upward firm's supply curve, a typical property in theory. This is because as yield increases, the firm must pay more for a single worker, either more wages or more safe expenditures.

(Figure 2)

2. Market Mechanism

Although a single firm's mortality rises with its yield, this does not mean that the industry's mortality also rises with the industry (or market) yield. Let's analyze the market mechanism now. For this, assume firms are homogeneous, so the industry's mortality is equivalent to a typical firm's mortality. Then the key is to understand how the *market* yield is related to a *firm*'s mortality.

Figure 3 analyzes the market mechanism. The graph on the left shows a single firm's supply

[5] In fact, one reason the government regards as typical for accidents is "excessive production", or "overly intensive exploitation". See "Case Studies of Coal Mine Accidents" in *China Coal Industry Yearbook*, 2005. pp. 741-773.

behavior. The graph on the right is on market supply and demand. It should be elementary exercises to study market outcomes by this figure. Let's consider influences of demand shocks on the coal market. Suppose there is a demand increase due to energy eagerness in economic expansions. When the demand increases, the market demand curve shifts right. The equilibrium yield increases, and also the price. The latter causes a typical firm to increase its yield; then a typical firm's mortality will increase. Conversely, when demand decreases, yield decreases and so mortality. In summary, demand changes result in a positive relationship between yield and mortality. A relationship between yield and mortality cause by shifts in demand is called *demand effect*.

(Figure 3)

Now let's consider influences of supply shocks. Analyzing an influence from supply side turns out to be more complicated. Our starting point is that market supply is determined by (only) two factors: a typical firm's supply and the number of firms in the market, by assuming homogenous firms. So we can have two types of supply shocks. Type I supply shock (or, industry supply shock) can only change the number of firms but not a single firm's supply behavior. Suppose a type I supply shock decreases the number of firms in the market, then the market supply will decrease, and so the equilibrium yield. In turn, the market price will increase, which makes a typical firm *still in the market* to increase its yield. Then the firm and industry's mortality will increase. In figure 3, this process can be shown as a leftward shift *of* the market supply curve, but a rightward shift *along* a typical firm's supply curve. We call such an effect *type I supply effect*, which results in a negative relationship between mortality and yield. Examples for type I supply effect include entry and exit of firms. Capacity adding or cutback by existing firms can also be regarded as a type I supply effect, since it changes the number of wells in operation, technically equivalent to changes of firm numbers.

Type II supply shock (or, firm supply shock) can only change a typical firm's supply but not the number of firms in the market. *Type II supply effect*, caused by type II supply shock, has ambiguous influence on the relationship between yield and mortality. It depends on specific factors we consider. To illustrate, let's list three factors – workers' alternative income, firm's safe endowments, and safe regulation on firms. Consider workers' alternative income. In China, this is usually farming income. With an increase of farming income as opportunity costs, mine workers require a higher wage and a better safety. This will increase a firm's cost and decrease its supply. In figure 2 this can be illustrated by a left-upward shift of the reservation utility curve. Usually it causes a decrease in mortality and in turn a positive relationship between mortality and yield. Secondly we consider safe endowments, natural conditions a mine faces. As an example, it is a common sense in the industry that more rainfall can be threatening. Besides, yield increase itself can be regarded as a deterioration of safe endowments. Similarly as yield increases, any safe deterioration increases both the mortality and wage. The firm's cost increases and supply decreases, resulting in a negative relationship between mortality and yield. It should be noted that technological progresses can be regarded as an improvement in safe endowments. Thirdly, let's consider government's safe regulation on firms. For example, a minimum requirement of a firm's mortality forces a firm to increase its safe expenditures and then (can) decrease wages. The firm's cost increases anyway, and supply decreases. Mortality will be positively related to yield.

3. Sum-up

Let's consider a useful benchmark, i.e., a free entry and exit coal market, without any intervention from governments. What kind of mortality-yield relationship can we expect? In the short run, shocks will mainly come from the demand. Consider a demand increase. At the very beginning, it's natural to suppose no firm will entry (or exit). The price will increase, and the yield of every existing firm increases. Then the mortality also increases, resulting in a positive relationship between mortality and yield. As time goes on, high price attracts newcomers. The yield will continue to increase, but the price will decease. A typical firm's yield then decreases, which pulls down the mortality. At this stage we see a negative relationship between mortality and yield. The entry will go on until the price goes back to its initial level. At that time, a single firm's yield and mortality will also go back to its initial level, but the market yield increase forever. Finally in the medium run, the mortality is *not* related to the market yield at all. However, if we give up homogeneity assumptions, so that newcomers have higher costs, yield and mortality can be positively related, although weaker than in the short run.

In the long run, shocks from firm's supply (type II supply) become the main force influencing the mortality-yield relationship. Consider a technological progress. This will usually decrease a single firm's mortality at the same time increase its yield, resulting in a negative relationship between them. However, consider another important factor - personal income increase cause by economic growth. It raises miners' reservation utility; both the mortality and yield decreases, resulting in a positive relationship between them. Both factors refer to a lower mortality for a more advanced economy; but predict opposite outcomes for coal yield. Besides, technological progress may even decrease the coal *demand*, and thus reduce its yield, by substituting more safe energy for it. As a whole, a long-run mortality-yield relationship is hard to specify. However, long-term evolutions are not our focus, when we observe changes within a decade or two.

Our analysis above implies that the mortality can fluctuate even if the yield does not: when demand forces drive changes in coal yield, the mortality can be either pro-cyclical or con-cyclical. However, in the medium run, an irrelevant or a slightly positive relationship between yield and mortality should be observed in a free market. Or, more importantly, a persistently negative mortality-yield relationship can only be observed if governments intervene the market, thereby type I supply effect plays extra roles.

Our following empirical analysis will delineate relationships between yield and mortality. Are they positively or negatively related, or not related at all? (An initial observation on figure 1 suggests a negative one.) Furthermore, we try to identify the three effects and compare their significances. Our results will have words to say on government interventions on China's coal market: Are there any indications of (real) government interventions? If any, how might it affect the mortality and yield? Any possibly unexpected consequences caused by government interventions?

4. Empirical Strategy

According to our theoretical framework, we propose a theory model made up of three equations. The first equation is market demand equation:

$$P = \alpha_1 + \underset{(-)}{\beta_1} * Q + \underset{(+)}{\gamma_1} * D + u_1, \qquad (1)$$

Where P is market price, Q is market yield; D represents other factors influencing the demand, or the demand effect. We set the sign of demand coefficient (γ_1) as positive. Obviously, the coefficient of yield (β_1) should have a negative sign. Notice that in this *demand* equation, the variable Q plays the role of *supply* effect (either type I or II).

The second equation is market supply equation:

$$Q = \alpha_2 + \underset{(+)}{\beta_2} * P + \gamma_{21} * S_I + \gamma_{22} * S_F + u_2, \tag{2}$$

Where S_I represents type I (or industry) supply effect, S_F represents type II (or firm) supply effect. Obviously the coefficient of price (β_2) should be positive.

The third and final equation is on the determination of mortality. It reflects a single firm's behavior:

$$M = \alpha_3 + \underset{(+)}{\beta_3} * P + \gamma_3 * S_F + u_3, \tag{3}$$

Where M represents the mortality. A single firm's mortality depends on price. Other things equal, an exogenous price rise increase its yield, thus the mortality increases; the coefficient of price (β_3) is positive. Besides, factors affect a single firm's supply (S_F) (at least partly) affect its mortality as well.

However, the price is an unobservable variable, due to lack of data. After all, coal price in China is heavily controlled by the government and does not reflect pure market forces. Therefore, we replace the price variable in equation (3) by using equation (1), and get the following equation:

$$M = (\alpha_3 + \alpha_1\beta_3) + (\beta_1\beta_3) * Q + (\beta_3\gamma_1) * D + \gamma_3 * S_F + (\beta_3 u_1 + u_3) \tag{4}$$

This is the equation we want to estimate. The coefficient ($\beta_3\gamma_1$) represents the demand effect, predicted to be positive. The coefficient γ_3 represents type II supply effect (on the mortality), with an ambiguous sign. The coefficient ($\beta_1\beta_3$) represents type I supply effect, predicted to be negative. Notice that although type II supply effect (S_F) is included in variable Q in theory (see equation (2)), empirically this effect has been absorbed by the variable S_F present in the equation.

Endogeneity Problem. Not surprisingly, the yield variable, Q, usually be endogenous. We see this by taking into account equation (2). Since Q and P, the price variable, are simultaneously determined by the demand (equation (1)) and supply (equation (2)), Q must be correlated with the residual item u_1. Besides, if we cannot completely control for type II supply effect (S_F), Q, with its links to S_F as in equation (2), is correlated with the residual item u_3. With our imperfect measurements of S_F, this will probably be the case.

To overcome the endogeneity, we should find some suitable instrumental variables (IVs) for the yield variable (Q). In our empirical analysis below, we will argue that, yield of the state-owned major enterprises (SMEs) is a good IV. Besides, if Q itself turns out to be exogenous, which is possible when the market supply elasticity with regard to price is zero, i.e., β_2 =0, and S_F has been fully controlled for, we can use Q directly as a regressand. We will use an endogeneity test to vindicate this assertion

Besides factors we discussed above, another possibility for an endogenous yield variable is government policy. The government might control the yield of a firm or all firms in a region according to its (or their) mortality. A higher mortality can lead to a stricter limitation on yield, resulting in a negative relationship between them. Whether this effect really exists depends on political economy, such as agent problems between central and local government, or enforcement problems as corruptions. It's hard to rule out such a reverse causality in a simple estimation. We try to solve it (although indirectly) in another way – a Granger causality test.

III. Macro-data Granger Test

We first use available macro (national level) time series data on yield and mortality to conduct a Granger causality test. The aim is to test causalities between yield and mortality from either way. A byproduct would be the sign of the lagged independent variable, which shows the direction (positive or negative) of a verified causality.

1. Regression Equation

The basic idea of the Granger test is to add into a variable's autoregressive model a lagged term of an independent variable to be verified. If the coefficient of this lagged term is significant, we verify that this independent variable is the cause of the dependent variable. As for coal yield on mortality, the regression equation is as followed:

$$Q_t = \delta_0 + \alpha_1 * Q_{t-1} + \ldots\ldots + \alpha_L * Q_{t-L} + \gamma_1 * M_{t-1} + \ldots\ldots + \gamma_N * M_{t-N} + u_t \tag{5}$$

Where L represents the number of lags included in the yield variable, usually determined by an autoregressive estimation, and N represents the number of lags included in the to-be-verified variable (here is mortality). The choice of N is not important for our purpose, and we choose it according to our sample capacity. A similar regression equation can be written to do the Granger causality test going from mortality to yield.

2. Data Source

The time span is from year 1994 to 2005 (altogether 12 years), all years when the mortality data is available. The coal yield is measured by "raw coal yield". The mortality is measured by the deaths in every million tons of coal produced, which is calculated, as defined, through dividing the number of deaths by the raw coal yield (in one million tons) in the industry per year. The data source is *China Coal Industry Yearbook* (various years). We do some adjustments on the data to make it consistent (For detail, see the data appendix). We also collect time series on coal price (previous year =100), which is available on national level (but not on provincial level). The measurement is "Ex-Factory Price Indices of Industrial Products" for the sector "Mining and washing of Coal". The data source is *China Statistic Yearbook*.

3. Results

Regression results are shown in Table 1. Group A is Granger tests on mortality-yield causality - mortality being cause and yield being effect. Regression (1) is yield's autoregression, with two lags included. In regression (2) we add the mortality variable to see if it is a cause of yield. The coefficient of the lagged mortality variable is insignificant. In regression (3) we replace mortality with the number of deaths, and in regression (4) we add time trend. The results of these two regressions are similar with regression (2). All the above regressions include all types of firm. In regression (5) – (7), we consider the mortality of different types of firms – the state-owned major enterprises (SMEs), State-owned local enterprises (SLEs), and Towns and Villages Enterprises (TVEs). The results are similar. So the mortality is not a (Granger-sense) cause of yield. This means that, governments in fact do not (or cannot) restrain yield by mortality. Two reasons are possible: governments (especially local governments) are unwilling to restraint output, even when face life losing, worrying that it retards economic growth; or, governments try to use the mortality as a standard for yield quotas, but they cannot implement it thoroughly (so called "dying cinders glowing again").

Group B is Granger tests on yield-mortality causality. Regression (1) is mortality's autoregression, with one lag included. In regression (2) we add the lagged yield variable (lagged once). The coefficient of yield is significantly negative, implying that a recent decrease in the yield will cause a mortality rise, an evidence of type I supply effect; the coefficient of the lagged mortality variable ceased to be significant. In regression (3) we add the second-order lag of yield, the results become more significant. In regression (4) we use price to replace yield. The results are not significant, however. Regression (5) – (7) considers three types of firms. Except for the SMEs, regressions for the other two types have similar results. All these results prove that yield is the (Granger-sense) cause of mortality.

In summary, our Granger test results show that yield causes mortality changes, but mortality cannot affect the yield. Besides, there seems some evidence of type I supply effect.

(Table 1)

IV. Provincial Panel Data Regression

Granger tests tell us yield indeed has influence on mortality. Now we use provincial data to further explore this influence, and identify all three effects it works through: demand effect, type I supply effect, and type II supply effect.

1. Regression Equation

According to our theoretical equations (mainly equation (4)), the regression equation is:

$$M_{it} = \alpha * Q_{it} + \beta * D_{it} + \gamma * S_{Fit} + \text{year}_t + \text{prov}_i + u_{it} \qquad (6)$$

Most variables have been specified in equation (4). Besides, "year_t" represents years' fix effect, implemented in regression by year dummies. It has two uses. First, it controls for common effects of macroeconomic fluctuations on provinces. Second, it controls for some data discrepancies among years. Although we have made adjustments on data to correct them, they might still partly remain. "prov_i" represents provinces' fix effect, showing that the econometric method we use is fix-effect panel data model. Fix-effect panel data model can eliminate endogeneity problems caused by provincial idiosyncrasies concerning mortality and yield, such as geologic structures.

2. Three Types of Firms

Due to data availability, we can consider the mortality and yield for three different types of firms (or coal mines), as well as consider them as a whole. Those three types are: the State-owned

Major Enterprises (SMEs), the State-owned local Enterprises (SLEs), and Towns and Villages Enterprises (TVEs). The last type is also called the Collective-owned Enterprises. Before we do econometric analysis, it is necessary to give an overview of the mortality and yield of those three types.

Appendix figure 1 shows the evolution of deaths for all three types. Two things are worth mentioning. First, the TVEs' number of death is quite larger than the other two, accounts for 70 percent of the total, although its yield proportion is never so large, always less than 50 percent. It is a truth then that the TVEs are riskier than their state-owned counterparts. Second, as for the fluctuations, the TVEs also dominate, implying less volatility of their counterparts.

Appendix figure 2 shows the evolution of yield. The SMEs, once called centrally-distributed coal mines, were the only important force in coal industry during the central planning time. After that, the decentralization reform encouraged local and private exploitation of mines. Some SMEs were even transferred to the lower level, their proportion in coal production decreased steadily. The TVEs began to play a significant role. In 1995, they produced even more than the SMEs for a while. Things changed soon after mid-1990s. The TVEs' yield turned down, and down a lot until 2000, when the whole economy began a new expansion. Both the SMEs and TVEs increased their yield, although the TVEs still produced less than the SMEs. As for the fluctuation of yield in the whole period, the TVEs still dominate. This might imply that only the TVEs respond in some degree to market environments, but not the others.

3. Variables and Data Source

The mortality (M) is the number of deaths in coal production divided by yield and the yield (Q) is measured by raw coal output, as we mentioned before. Data source for them are still *China Coal Industry Yearbook*, where the number of deaths has inconsistent measures among years and we have to adjust them (See data appendix).

We use three demand variables (D): secondary industry output (value added), electric power consumption, and winter average temperature. Secondary industry output reflects local demand on energy and raw material. Since coal is the main input in electric power, metallurgy, construction, chemical industry, and so on, secondary industry output can capture the whole industrial coal demand, although it covers a broader scope than we expect. Data source for it is *Data of Gross Domestic Product of China* (1996-2002) and *China Statistic Yearbook*. Electricity generating is coal's main use; almost half of annual yield is used in it. Given generators' capacity, electric power consumption mainly reflect demand rather than supply of coal[6,7]. Winter average temperature measures demand for house warming in winter. Due to lack of data on provincial level, we use the capital city's temperature (averaged on January, November and December) in each province. Signs of all three demand variable are expected to positive.

Type II (firm) supply effect are measured by three variables: farming income, annual rainfall, and a dummy on whether there has been any major accident with more than 30 persons killed in the past year starting from the mid-year. Farming income is measured by "income from household operations", which is part of "net income of rural households". Annual rainfall measures natural conditions as safe endowments. Since we have no regional rainfall data, we replace with capital

6 We also try to use thermal electric energy production to replace electric consumption. The results are not satisfying; we even have an opposite sign from expectations. The reason might be that thermal electric energy production may reflect both coal demand and coal supply. For example, we usually build "pithead power plant".

7 Although there are other electricity generating sources, such as water, wind, and nuclear power, thermal power is still the main source and roughly 70 percent of electric power is from it.

cities' rainfall. The data source of these two variables is *China Statistic Yearbook*. The dummy variable is used as a proxy for safety regulations on firms; more nearby accidents usually imply more strict regulation, and less mortality. However, this dummy can also include some industry (type I) supply effects from regulations. For example, governments may ask for more shutdowns in a region with more accidents. If so, we will underestimate type I supply effect. Data source is *China Coal Industry Yearbook*. Signs of farming income and the accident dummy should be negative; that of rainfall should be positive.

For sampling space, the available years are 1995-2000, restrained by the mortality data. We have 27 provinces, ruling out 4 provinces in China: Tianjin, Shanghai, Tibet and Hainan, where no coal is produced. Chongqing's data is from 1996, the year it was separately counted. Before that it is included in data of Sichuan province. To make data consistent, we delete Sichuan's data in year 1995.

4. OLS Results

Table 2 (Except regression (3), (6), (9) and (12)) shows the results. We regress the mortality for each type of firms, and all firms as a whole. However, the yield variable is only market yield, including all types of firms. In regression (1), (4), (7) and (10), we do the simplest two-variable regressions to see the correlation between mortality and yield. We find a strongly negative relationship between them, as we perceived before. In other regressions, we control for demand and type II supply effect, as the regression equation (equation (4)) specify. The result is quite clear: coefficients of yield are all negative as we expect: As the yield decreases, the mortality increases. Looking at different firms, the coefficient is most significant for the TVEs, quite significant for the SLEs, but insignificant for the SMEs. Type I supply effect turns out to be prominent.

Type II supply effect is not significant as a whole. The F-test for joint significance has a p-value always below 0.2. Only farming income variable is barely significant. Contrarily, demand effect is jointly significant. Separately, in the total mortality regression (regression (2)), secondary industry output is significant and has the expected sign; in regressions for each type of firm's mortality, electric power consumption turns to be significant often and has the expected sign. It is most significant for the TVEs, and quite significant for the SLEs. For the SMEs, all the demand variables are not significant, implying that the SMEs may respond little to the market[8, 9].

In summary, type I supply effect plays a significant role in the market. Demand effect also plays a role but les significant. No evidence has been found for a role of type II supply effect. Since type I supply effect dominates, we should, and indeed, see a negative relationship between yield and mortality. Besides, the TVEs and SLEs are more responsive to demand or supply changes than the SMEs.

Let's quantify our findings. When the market yield (more precisely, supply) decreases 1 percent, the SLEs' mortality increases 0.01*6.55/6.64=1.0 percent (6.64 is the average mortality of this type of firms, see appendix table 1), the number of deaths remains the same. The TVEs'

[8] We put all the three demand variables together in the regression. We also try each separately. The result is quite similar. Although putting them together may induce a multicollinear problem, it can also control more fully for the demand effect.

[9] Someone may argue there should be an "adverse selection" effect in the market. When the price increases due to more demand or less supply, safer (thus with higher cost) enterprises will enter the market. Such an effect will blur our analysis somehow. To control for this, we try to add a new variable, the yield ratio of SMEs to TVEs, to capture such an effect in regression (2). The result shows that the coefficient of this ratio is significant and negative as expected: β=-.19, p-value=0.001. However, this changes little both the coefficient and significance of our yield variable (Q): β=-7.45, p-value=0.000. Thus even if we control for the possible adverse selection problem, type I supply effect is still very strong. I thank Bai Chong-en for relevant advices.

mortality increases 0.01*35.02/16.57=2.1 percent; and the number of deaths increases 1.1 percent. There are almost no changes in mortality for the SMEs.

(Table 2)

5. IV Methods and Results

The previous analysis can be called an "aggregated effect" analysis. We regressed all kinds of mortality on the *aggregated* market yield. Now we turn to so-called the *self-effect* and *cross-effect* analysis, i.e.., we consider how yield of each type of firms affects the mortality of its own and others. According to our theoretical model, this is a thing we should NOT do, since what affects a single firm's mortality is the market yield as a whole (through the market price). The aggregated effect is only the effect we need to test. So what's the reason for a self- and cross-effect estimation?

The answer is that this will help us find, reasonably, a proper instrumental variable. To understand this, let's go back to our theoretical equations. First, let's decompose the market supply (equation (2)) to supplies from different types (denoted as i) of firms:

$$Q = \Sigma Q_i = \Sigma(\alpha_{2i} + \beta_{2i}*P + \gamma_{21i}*S_I + \gamma_{22i}*S_{Fi} + u_{2i}) \qquad (2')$$

For any type-*i* firms, the regression equation (equation (4)) should be written as,

$$M_i = (\alpha_{3i} + \alpha_1\beta_{3i}) + (\beta_1\beta_{3i}) *Q + (\beta_{3i}\gamma_1) *D + \gamma_{3i}*S_{Fi} + (\beta_{3i}u_1+ u_{3i}) \qquad (4')$$

Then it's easy to see that, the yield of some type (say, type *j*) of firms, Q_j, can be used as an IV for the market yield, Q, in equation (4'), if Q_j is not correlated with the residual terms u_1 and u_{3i}. (Besides, Q_j should be correlated with Q. This is usually true if Q_j is a significant part of Q.) For Q_j uncorrelated with u_1, we should have: $\beta_{2j} = 0$. I.e., Type-j firms do not response to price changes. Besides, if type-*i* firms' (type II) supply effect (S_{Fi}) has been fully control, there should be no correlation between Q_j and u_{3i}. Even if S_{Fi} is not fully controlled, this correlation can be ruled out if the type II supply effects remained in the error term are independent between different types of firms (when $i \neq j$). If all the above conditions are satisfied for a yield variable under consideration, it can be used as an IV.

We now want to see if yield of some type of firms can be used as a proper IV. But before we really argue for the above *sufficient* conditions, we first look at a *necessary* condition. Suppose yield of one type of firm can be used as an IV, that is, it is an exogenous variable. Then the self-effect and cross-effect regressions on it are exactly the reduced-form regressions for the corresponding IV regressions. According to our theory, we should expect: First, it should have a negative cross-effect on the mortality of other types of firms; second, its self-effect should also be negative.

Table 3 shows brief results of self- and cross-effect regressions. The self-effect of the SLEs is significantly negative, but their yield has insignificant effect on the mortality of other types. The reason might be that the yield of SLEs has been a small and stable portion of total yield, thus cannot capture changes of total yield. The TVEs have a significantly negative self-effect, but their yield has a significantly positive effect on the SMEs' mortality. This implies that their yield might be endogenous: Since the TVEs may response more to the market, the condition $\beta_{2j} = 0$ may not be satisfied. As a whole, neither the yield of the SLEs nor that of the TVEs can be used as an IV, according to our conditions specified above.

In contrast, yield of the SMEs has a very significantly negative effect on the mortality of the other two, satisfying our first condition. Although its self-effect is insignificant, it may not imply endogeneity. It might be that the SMEs' mortality itself is not responsive to the yield, i.e., $\beta_{3i} =0$, since the SMEs face more rigorous safety regulations. This assertion is consistent with our previous regressions on the SMEs' mortality (see regression (4)-(5) in table 2), where the SMEs' mortality seems uncorrelated with anything we consider. So a weak self-effect may not affect the reliability of the SMEs' yield as an IV. Based on this, we intend to use the yield of the SMEs as an IV for the market yield, Q[10].

(Table 3)

We now select the SMEs' yield as our single candidate as an IV, from the self- and cross-effect regression as a necessary condition. For sufficient conditions of its exogeneity, we now try to find out determinants of the SMEs' yield, to see whether the yield is determined by demand or supply force. The result is shown in column (1) and (2), table 4. From column (1), it seems that the yield is determined by demand forces (through price) and thus endogenous. The demand variables, especially the secondary industry output and electric power consumption, are very significant. But when we add a new variable, the certificated capacity of the SMEs[11], all the demand variables ceased to be significant and only this capacity variable is significant. The certificated capacity reflects firms' supply conditions, and must be proved by the governmental sector in charge. It should be a supply variable. We also use the capacity variable as an IV for the SMEs yield to regress the market yield (Q). Regression the market yield on the SMEs' yield is just the first-stage regression of the two-stage lease square (2SLS) IV regression for the mortality, which we focus on. When the capacity variable is not introduced as an IV (shown in column (3) of table 4), the SMEs' yield already has a significant positive coefficient, showing that it is highly correlated with the market yield. When the SMEs' yield is instrumented by the capacity variable, its significance does remain (shown in column (4) of table 4). In summary, since the certificated capacity represents supply effect, and the SMEs' yield is mainly determined by the capacity, the SMEs' yield should be an exogenous variable.

(Table 4)

Now we will use the SMEs' yield as an IV for the market yield to regress the mortality. But

[10] Here is another evidence for the exogeneity of the SMEs' yield. In 1997, the then Ministry of Coal Industry issued a document "A Notification from the Ministry of Coal Industry on 'Double Controls' Quotas of Raw Coal Yield and Stock in 1998", where specified yield in 1998 for each of the SMEs.

[11] According to " Management Rules on Coal Production Capacity", newly updated in 2006 by National Reform and Development Commission and the SAWS, " the certificated capacity is the capacity registered on the coal production license of coal mines, for those who have legally acquire such a license. It can also be updated by year for those whose capacity has deviated from reality due to geological or technical conditions and has been re-checked and re-approved by the license-issuing government sectors". "It is the maximum level a coal mine can produce in a year." Data source is still *China Coal Industry Yearbook*.

before that, we briefly describe possible channels the SMEs' yield could affect any firm's mortality. From equation (2'), we can see that there are two channels. One is through type I supply effect (S_I), as we expect. It implies that changes of the SMEs' yield (or supply) just represent those of all firms' supply in the markets. In other words, different types of firms have complementary changes, due to some common supply shocks, for example, government regulations on the whole market. There is also another channel, where only the SMEs themselves are affected by some supply shocks, represented by S_{Fi} in equation (2'). From other firms' point of view, this is also a type I supply effect. However, this kind of effect will affect the SMEs and other firms in an opposite direction: yield changes should be substitutes for each other, rather than complements[12].

The IV regression results are listed in column (3), (6), (9) and (12) in table 2. All the results show that type I supply effect is still significant. In particular, type I supply effect in the SLEs' and TVEs' mortality regressions is enhanced. As the market supply decreases 1 percent, the SLEs' mortality increases 0.01*11.67/6.64=1.8 percent, with the death number increasing 0.8 percent. The TVEs' mortality increases 0.01*66.28/16.57=4.0 percent, with the death number increasing 3 percent. The Result for the SMEs' mortality changes little. In summary, IV regression results provide further evidences on significance of type I supply effect.

6. Robustness Check

In this section, we first test whether the market yield is exogenous. As we have justified, the SMEs' yield is indeed exogenous. Although the yield of the SLEs and TVEs is more responsive to the market, it is also regulated by the government. So there are reasons for the market yield as a whole to be exogenous.

What we use is so-called endogeneity test (For reference, see Woodridge (2003), pp. 506-507). The null hypothesis of this test is that the variable to be verified is exogenous. Such a test cannot use panel-data fix-effect model, so we first differentiate every variables and use the OLS regression. The regression equation is as below:

$$\Delta Q = \pi_0 + \pi_1 * \Delta D + \pi_2 * \Delta S_F + \pi_2 * \Delta Z + \text{year} + v_2 \quad (7)$$

Where Z is an extra exogenous variable, here is the SMEs' yield. After regressing this equation, we then introduce its estimated residuals into equation (4) as:

$$\Delta M = \alpha * \Delta Q + \beta * \Delta D + \gamma * \Delta S_F + \delta * \bar{v}_2 + \text{year} + u \quad (4'')$$

If the coefficient δ is insignificant, we cannot reject our null hypothesis. The market yield (Q) can be verified in this test as exogenous.

The endogeneity test results are shown in table 5. We cannot reject the hypothesis that the market yield is exogenous. This explains why our mortality regression results are qualitatively the same with or without IVs.

(Table 5)

[12] We use the yield (rather than mortality) of different types of firms as the explained variables to do a similar regressions as we do in table 3. All the coefficients are positive, which means complement rather than substitute effects may dominate. The result is not listed here.

We also do other robustness checks. For example, we can observe a clear drop of the mortality after year 2003 (See appendix figure 1). There are some guesses that after the central government's tightened its safe regulations, local governments began to under-report the mortality numbers. Our year dummies have already controlled for this, at least partially. Here we split the data into two periods, years before and after 2003, and do separate regressions. There are no essential changes on the results. In some regressions, the coefficient of the yield (type I supply effect) is economically or statistically more significant after year 2003, an evidence supporting those guesses, while in other cases, the opposite is true[13].

V. Conclusions and Implications

Our theoretical and empirical analysis clearly shows that, the actually existing negative relationship between mortality and yield should be contributed to type I supply effect, the effect that changes the market supply in the way of changing the numbers of firms (or wells) in the market but not a individual firm's supply. We conclude in the following way. We will describe changes of yield and mortality in some specific periods, to see how the theory can explain what happened.

1. Year 1996-1999

From the appendix figure 1 and 2, we can see that, in this period, the TVEs experienced a yield drop as well as a rise in death and (needless to say) the mortality. This seeming puzzle can be well explain by our theory on type I supply effect.

Where did these type I effects come from? Government policy might be an issue. From mid-1990s, various restraints have been exerted on the TVEs. Before that, and since 1980s, the government had been encouraging set-ups of local small coal mines. However, more and more problems had been found as time went on. For example, those small TVEs often exploited beyond their legal bound and threatened the SMEs' production. Besides, the TVEs dig in a primitive way and wasted resources. As the economy slowed down after the mid-1990s, governments saw good opportunities to close *all* these small firms, not only in coal industry but also in other industries.

One important way to implement such a policy is licensing. In 1986, the central government published the "Mineral Resource Law" and the first license, "mining license", was born. Every prospector should acquire this license before he (or she) can access any mineral resources. In 1994, the State Council published the "Administration Rules on Coal Production Licenses", which requires each coal mine should acquire another license, "production license", from the coal industry administration in charge. Furthermore, any coal who wants to have this license must acquire the mining license, and another certificate called "Qualification Certificate for the Miner-in-charge" first. Thus after year 1994, three independent licenses should be held together to open a legal mine, not to mention the normal "business license" any firm should acquire from the business administration. Governments still tried to build on the licensing system recently. In 2004, the State Council published the "Byelaw on Safe Production License", which requires all the mining and construction firms must acquire the "safe production license" before they can produce anything. Licensing is only one way to regulate coal mines, when needed. Other methods include "safety rules" published by governments to directly regulate the production process, safety

[13] I thank Ning Xiangdong and Lin Xu for relevant advices.

supervisions, safety ranking system, and direct quotas or even shutdown[14].

The aim is, of course, to make coal mines safe and orderly. But such policies can also lead to unexpected consequences. They can increase rather than decrease the mortality (even the deaths) through type I supply effect we state. Besides, many firms who cannot acquire so many licenses choose illegal production. They escape from government day-cares, but feel no better since they can be shutdown suddenly in one nigh. Their incentives are to excessively exploit, which leads to more accidents.

2. Year 2002 till Now

At this period the coal mine deaths have been steadily dropped (see appendix figure 1). It sounds strange, since after 2000, we experienced a strong economic expansion. The demand for coal increased, and the mortality and the deaths should have increased. So what account for this death decrease?

By examining the data (especially appendix figure 2), we can find some hints. First, the yield of the SMEs, which remained stable in the past, began to increase rapidly in these years. In 1990, the SMEs produce a yield of 0.48 billion tons. This number increase to only 0.53 billion in 2000. But in 2005, the yield has reach 1.02 billion tons! Obviously such a huge increase cannot be only regarded as 'response to demand" but also, or even mainly as supply explosion, a type I supply effect due to more wells. "Big mine, big death" had been the headlines, but it might imply a lower mortality for the whole industry. In fact, this phenomenon is well captured by our empirical analysis including the SMEs' capacity as an element.

Secondly, and even more interestingly, the yield of the TVEs also increased a lot. In 2005, the TVEs' yield is 0.84 billion tons, a historically highest level. Before that, the highest level is 0.61 billion tons in year 1996. As we know, this is a period when governments strengthened its control over small coal mines. What really happened might be the opposite.

3. Conclusions

Out research has a policy implication beyond coal industry itself. A well-designed government policy should consider all effects it imposes on the market. If not, to correct market failures, if any, government failures unavoidably step in. Sometimes governments even perform worse than the market. Studies on interactions between governments and the market are eternal themes for economists.

Our research still has drawbacks. Most importantly, we do not find any policy variables to directly measure government's influence on the market. For example, we fail to collect reliable data on the numbers of wells closed by local governments. We also cannot measure the regulation enforcement among regions to see their influences on the market. Those will be our future research subjects.

Data Appendix: Mortality

From *China Coal Industry Yearbook* (1996-2005) (thereafter *yearbook*) we can find provincial death numbers in year 1995-2005. For national level data, 1994 is also available. The mortality is the death number divided by the coal yield (in millions of tons). Although in some years, the mortality data is directly available, we do not quote them. Instead we calculate all by

[14]From 1988 to 2005, Governments never stopped to issues new provisions to emphasize "cutback and shutdown" policies. Our incomplete count is that there are at least 8 provisions from the level of the State of Council, not to mention those from the lower level governments.

ourselves, to keep all these data consistent.

The provincial statistics on death numbers includes three types of firms: the state-owned major enterprises (SMEs), the state-owned local enterprises (SLEs) and the Towns and Villages Enterprises (TVEs), also called the Collective-owned enterprises. Besides, the fourth type, “small well managed by the state-own major enterprises” (SWSMs), can also be found for year 1995 to 2001. After that, it disappeared since governments commanded shutdowns of those wells. Our analysis does not include this type, because it has no separate yield data. Besides, its death number is small and quite stable (See appendix figure 1, where we includes this type.)

The death number has three different measures: death number in raw coal production (D1), death number in coal production (D2), and death number in coal industry (D3); each is included in the next. The *yearbook* only names but does not explain those measurements. However, we derived their relationship from a table in the *yearbook*, where all those measures are listed together. D1 refers to the death number in the exploiting operations. D2 refers to the number in both exploiting and processing operations. D3 refers to the number in any production process, as well as mine constructions – structure and facility building activities. Not all types of firms have all three measures. For the TVEs, we only have one measure. In fact, we only need one measure, since the TVEs almost do nothing in processing and constructions.

For the national level data, all three measures have available data, at least can be calculated. The data for year 1996 is different: for the SLEs and TVEs, we only have mortality rather than death numbers. We derive death numbers by combing the mortality and yield data. In this paper, all the national level data uses the biggest measure, D3.

Provincial data is more troublesome. The *yearbook* contains only one measure each year, and contains different measures in different years. The yearbooks for 1995-98 contain only D1, 1999-2002 only D2, 2003-05 only D3. We try to adjust different measure to D2, which has a longer time-length than others. To adjust D1 data to D2, we calculate a ratio of D1 on D2 by using the national level data, and transform each provincial D1 data to D2 by multiplying this ratio. We approximate D3 as D2, since the difference, the death number of mine constructions, is very small. All those adjustments are only needed for the SMEs and SLEs.

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Table 1 Mortality and Yield: Granger Causality Test

Group A: Yield as Effect, Mortality as Cause (Explainde Variable: ln[yield(t)])							
Explanatory Variables	All Firms				SMEs	SLEs	TVEs
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln[yield(t-1)]	1.76 ***	1.83 ***	1.78 ***	1.55 **	1.55 ***	0.50	1.25 *
	(0.19)	(0.39)	(0.22)	(0.44)	(0.41)	(0.45)	(0.65)
ln[yield(t-2)]	-1.16 ***	-1.16 ***	-1.17 ***	-1.00 **	-0.44	-0.59	-0.87 ***
	(0.26)	(0.30)	(0.27)	(0.29)	(0.58)	(0.46)	(0.22)
mortality(t-1)		0.02		0.00	0.15	-0.16	-0.01
		(0.08)		(0.07)	0.12	0.13	0.06
ln[death(t-1)]			-0.13				
			(0.40)				
Time Trend				0.02			
				(0.01)			
Prob>F	0.00	0.00	0.00	0.00	0.00	0.05	0.00
Adj. R-sq	0.94	0.94	0.94	0.96	0.96	0.60	0.81
# of samples	10	10	10	10	10	10	10
Group B: Mortality as Effect, Yield as Cause (Explained Variable: mortality(t))							
Explanatory Variables	All Firms				SMEs	SLEs	TVEs
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
mortality(t-1)	0.86 ***	-0.04	-0.30	0.73 ***	-0.48 ***	1.23	0.08
	(0.14)	(0.36)	(0.34)	(0.21)	(0.16)	(0.67)	(0.35)
ln[yield(t-1)]		-4.58 **	-8.37 ***		0.90 *	-2.22	-11.12 **
		(1.94)	(2.29)		(0.43)	(2.29)	(3.67)
ln[yield(t-2)]			4.60 **		-2.18 ***	2.75	7.57 **
			(1.86)		(0.47)	(2.10)	(2.51)
ln[price(t-1)]				-3.74			
				(3.10)			
Prob>F	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Adj. R-sq	0.57	0.69	0.85	0.63	0.85	0.83	0.75
# of sample	11	11	10	11	10	10	10

Note: Stand errors are in the parentheses. ***=1%, **=5%, *=10% significance. "ln( )" means logarithm of a variable.

Table 2 Mortality and Yield: Panel Data fix-effect Regression Results

Explanatory Variable	Explained Variable: Mortality											
	All Firms			SMEs			SLEs			TVEs		
	(1)	(2)	(3)-IV	(4)	(5)	(6)-IV	(7)	(8)	(9)-IV	(10)	(11)	(12)-IV
ln(Yield)	-8.26 ***	-8.59 ***	-4.03 **	-1.38	-0.91	0.65	-6.08 ***	-6.55 ***	-11.67 ***	-29.27 ***	-35.02 ***	-66.28 ***
	(1.49)	(1.48)	(1.99)	(1.39)	(1.46)	(2.21)	(1.96)	(2.04)	(3.01)	(6.86)	(7.18)	(13.79)
Firm's supply												
ln(farming inc.)		-8.24 ″	5.09		-5.58	-5.84 ″		-9.95	-5.38		22.00	-28.72
		(5.57)	(5.85)		(4.11)	(4.13)		(7.27)	(7.30)		(22.76)	(29.75)
ln(rainfall)		0.21	0.43		-0.66	-0.71		-0.01	0.62		1.26	7.30
		(1.32)	(1.03)		(1.06)	(1.07)		(1.85)	(1.82)		(6.50)	(7.57)
recent acc.(Dum)		-0.43	-0.58		-0.18	-0.11		-0.25	-0.74		-5.81	-7.28 ″
		(0.95)	(0.69)		(0.66)	(0.67)		(1.23)	(1.13)		(4.41)	(4.80)
Prob>F,X_sq		(0.49)	(0.65)		(0.52)	(0.48)		(0.59)	(0.79)		(0.45)	(0.26)
Demand												
ln(sec. output)		13.47 **	5.77		3.42	3.21		9.27	4.57		-5.87	-15.66
		(6.85)	(5.44)		(4.75)	(4.77)		(7.72)	(8.12)		(27.22)	(34.03)
ln(elec. cons.)		4.27	2.89		-3.30	-4.03		10.83 **	8.72 **		61.74 ***	96.53 ***
		(4.29)	(3.11)		(2.71)	(2.83)		(4.53)	(4.24)		(16.73)	(19.71)
winter temp.		0.07	0.05		0.09	0.09		0.06	0.10		0.27	0.50
		(0.13)	(0.10)		(0.12)	(0.12)		(0.21)	(0.20)		(0.74)	(0.82)
Prob>F,X_sq		(0.03)	(0.24)		(0.56)	(0.46)		(0.01)	(0.10)		(0.00)	(0.00)
Year Fix-effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prov. Fix-effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prob>F,X_sq	0.00	0.00	0.00	0.49	0.58	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Adj. R-sq	0.26	0.32	0.36	0.05	0.07	0.07	0.10	0.15	0.16	0.15	0.20	0.28
# of sample	189	189	154	234	234	234	276	276	224	286	286	231

Note: Stand errors are in the parentheses. ***=1%, **=5%, *=10%, ″=15% significance. “ln( )” means logarithm of a variable.

Table 3 Mortality and Yield: Self-effect and Cross-effect

	Mortality		
	SMEs	SLEs	TVEs
ln(Yield)			
SMEs	0.27	-7.69 ***	-40.11 ***
	(1.24)	(1.98)	(8.52)
SLEs	0.14	-9.70 ***	1.51
	(0.80)	(1.17)	(4.73)
TVEs	1.52 **	-1.87 *	-31.93 ***
	(0.78)	(1.08)	(3.53)

Note: Stand errors are in the parentheses. ***=1%, **=5%, *=10% significance. “ln( )” means logarithm of a variable. The regression model is equation (6).

Table 4 Determinants of SMEs and Market Yield

Explanatory Variable	Explained Variable			
	ln(SME Yield)		ln(Total Yield)	
	(1)	(2)	(3)	(4)-IV
ln(cer. capacity)		0.39 ***		
		(0.10)		
ln(SMEs yield)			0.63 ***	0.70 ***
			(0.04)	(0.17)
Firm's supply				
ln(farming inc.)	0.14	-1.05 "	0.02	-0.14
	(0.27)	(0.74)	(0.16)	(0.51)
ln(rainfall)	0.17 **	0.01	-0.02	-0.01
	(0.07)	(0.09)	(0.04)	(0.06)
recent acc. (Dum)	-0.01	0.05	-0.03	0.00
	(0.04)	(0.06)	(0.03)	(0.04)
Prob>F,X_sq	(0.10)	(0.46)	(0.64)	(0.99)
Demand				
ln(sec. output)	0.88 ***	0.00	-0.26	-0.22
	(0.31)	(0.71)	(0.19)	(0.45)
ln(elec. cons.)	0.43 ***	-0.02	-0.16 *	0.03
	(0.16)	(0.52)	(0.10)	(0.34)
winter temp.	0.00	-0.04	0.00	0.01
	(0.01)	(0.03)	(0.00)	(0.02)
Prob>F,X_sq	(0.00)	(0.71)	(0.07)	(0.89)
Year Fix-effect	Yes	Yes	Yes	Yes
Prov. Fix-effect	Yes	Yes	Yes	Yes
Prob>F,X_sq	0.00	0.00	0.00	0.00
Adj. R-sq	0.36	0.46	0.77	0.79
# of sample	239	88	239	88

Note: Stand errors are in the parentheses. ***=1%, **=5%, *=10% significance. "ln( )" means logarithm of a variable.

Table 5 Endogeneity Test on Yield

(Prob>|t|)	Mortality			
	All Firms	SMEs	SLEs	TVEs
Z variable				
SMEs' Yield	0.26	0.60	0.52	0.53

Note: Numbers in the table are p-value of the coefficient δ.

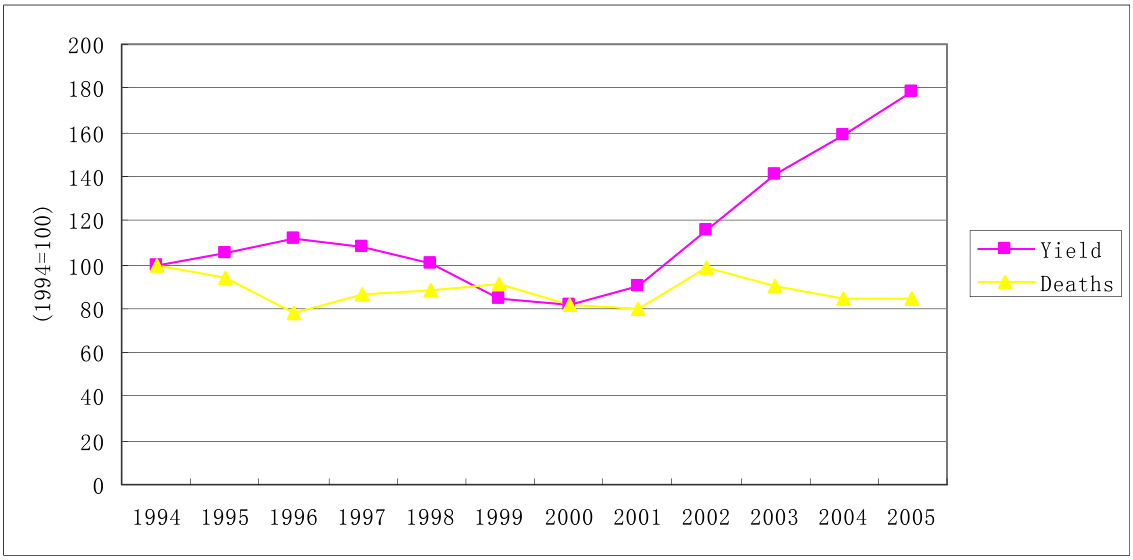


Figure 1 Coal Yield and Deaths (1994-2005)

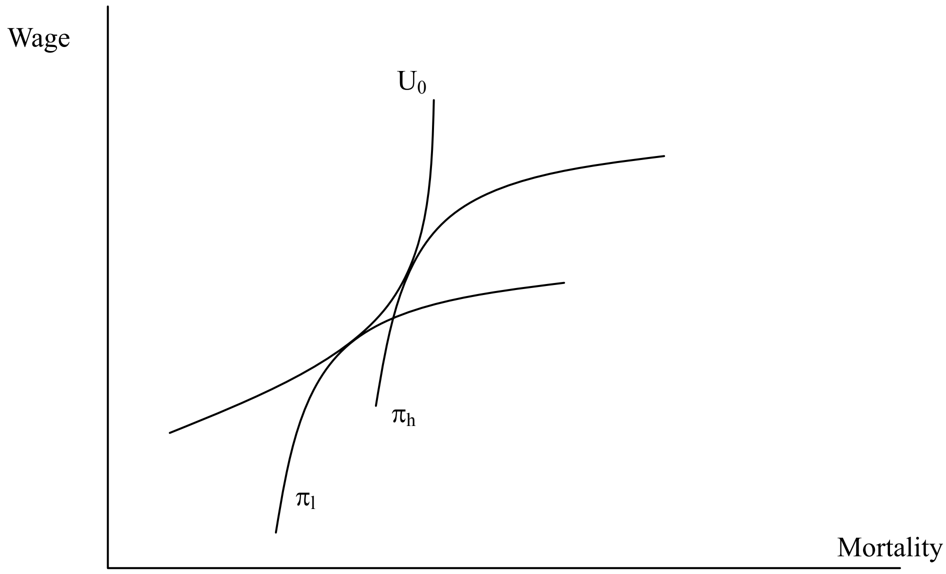


Figure 2 A Single Firm's Yield and Its Mortality

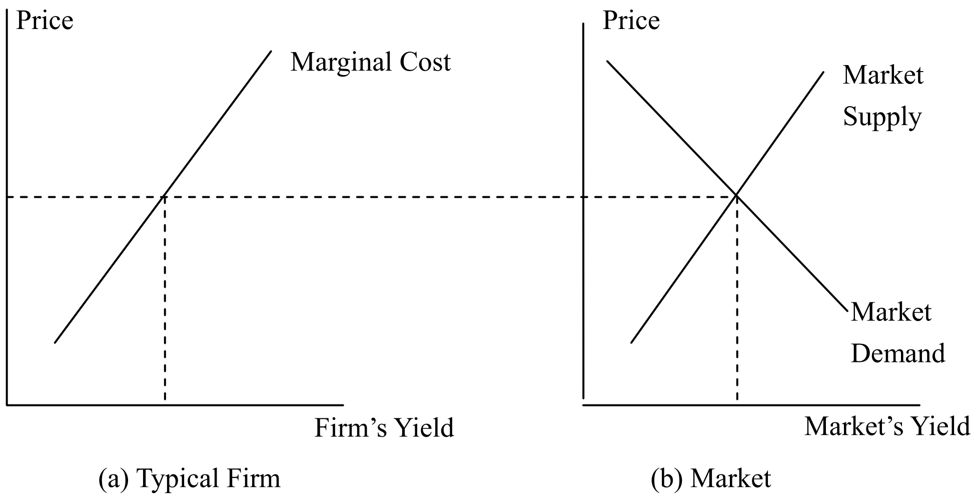
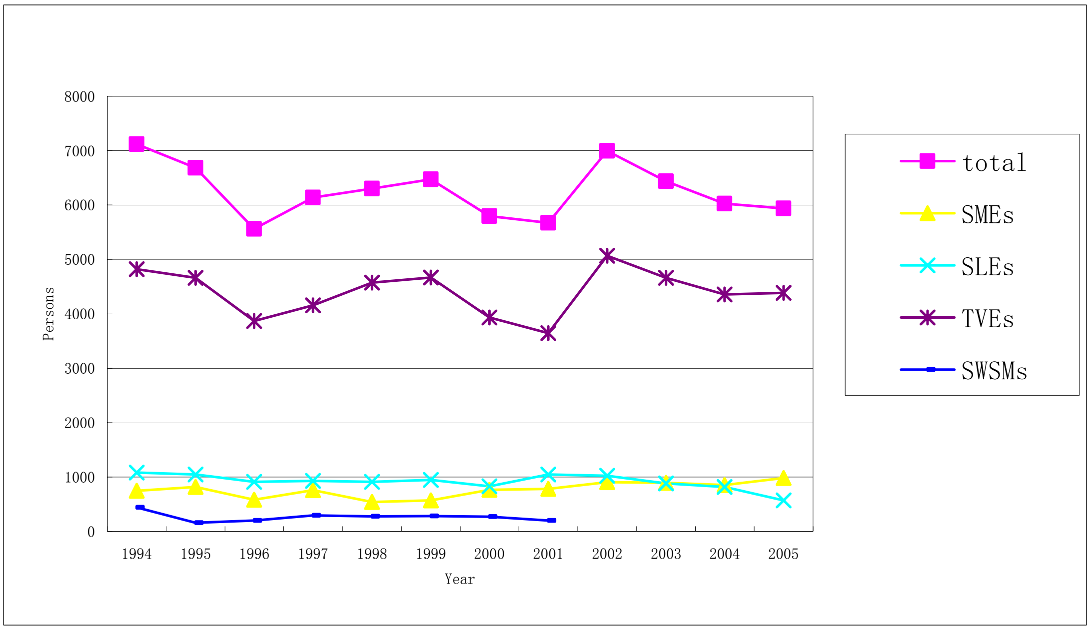


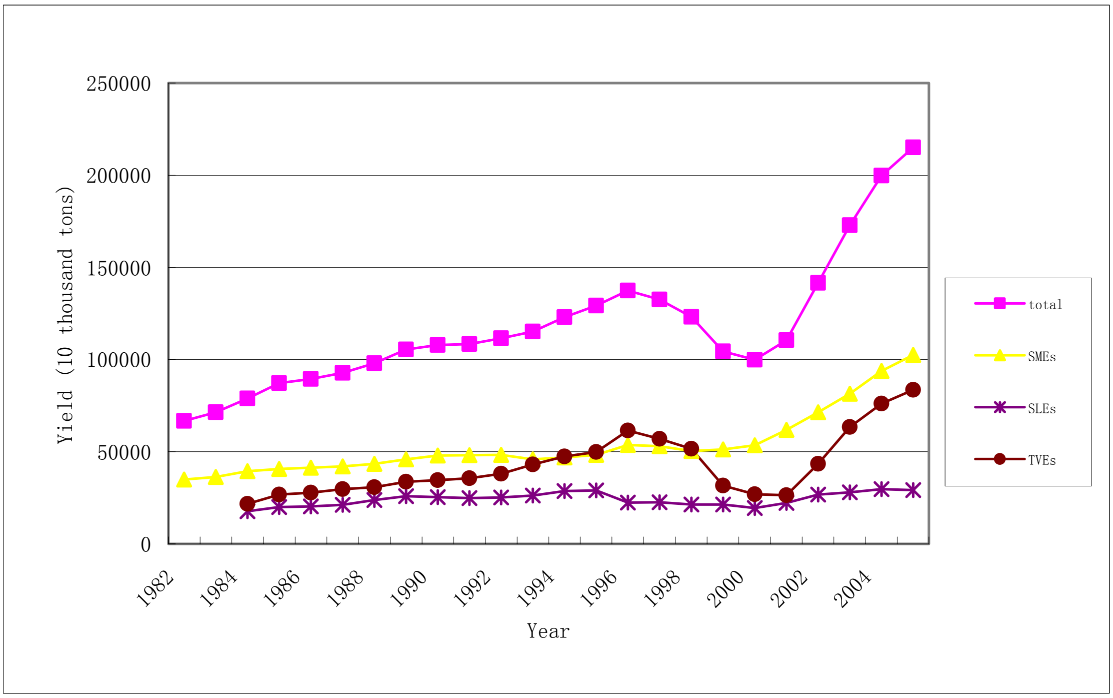
Figure 3 Market Mechanism

Appendix Table 1 Statistic Summary

Varible	Unit	N	Mean	Std. Dev.	Min	Max
National Level						
Raw Coal Yiled (Total	10 thousand tons	12	140781.50	36651.28	99917.00	215132.00
Raw Coal Yiled (SME	10 thousand tons	12	63995.83	18973.60	46867.00	102421.00
Raw Coal Yiled (SLEs	10 thousand tons	12	25040.25	3784.43	19426.00	29681.00
Raw Coal Yiled (TVEs	10 thousand tons	12	51583.92	18140.76	26385.00	83551.00
Mortality (Total)	/million tons	12	4.70	1.09	2.73	6.20
Mortality (SMEs)	/million tons	12	1.24	0.25	0.91	1.69
Mortality (SLEs)	/million tons	12	3.74	0.78	1.95	4.68
Mortality (TVEs)	/million tons	12	9.59	3.43	5.25	14.72
Ex-Factory Coal Price	previous year=100	12	109.08	9.26	94.80	123.20
Provincial Level						
Raw Coal Yiled (Total	10 thousand tons	294	5296.07	7372.75	51.00	55416.00
Raw Coal Yiled (SME	10 thousand tons	239	2992.30	3802.70	42.00	25621.00
Raw Coal Yiled (SLEs	10 thousand tons	284	957.12	1195.54	1.00	8560.00
Raw Coal Yiled (TVEs	10 thousand tons	287	1973.21	3106.81	1.00	21252.00
Mortality (Total)	/million tons	189	8.07	7.63	0.27	57.24
Mortality (SMEs)	/million tons	234	2.61	4.34	0.05	50.59
Mortality (SLEs)	/million tons	276	6.64	9.52	0.22	100.00
Mortality (TVEs)	/million tons	286	16.57	33.06	0.36	400.00
Farming Income	RMB Yuan	294	1477.13	383.17	723.16	2789.40
Sec. Output	1995=100	297	195.44	78.96	100.00	501.65
Elec. Consumption	hundred million kilowatt	294	529.89	397.73	69.02	2673.56
Winter Temp.	degree centigrade	297	3.68	7.70	-15.43	17.17
Rainfall	millimeter	297	862.79	496.34	74.90	2678.90
Recent Acc. (Total)	Dummy	297	0.22	0.41	0.00	1.00
Recent Acc. (SMEs)	Dummy	297	0.09	0.28	0.00	1.00
Recent Acc. (SLEs)	Dummy	297	0.04	0.19	0.00	1.00
Recent Acc. (TVEs)	Dummy	297	0.12	0.32	0.00	1.00



Appendix Figure 1 Deaths in Coal Mine Industry



Appendix Figure 2 Raw Coal Yield