Environmental Political Business Cycles
The Case of PM2.5 Air Pollution in Chinese Prefectures[*]

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Abstract: Chinese local leaders' behaviors are driven by a career incentive structure in which those delivering better performances are more likely to be promoted. Local leaders signal competence when their superiors actively collect evidence to evaluate their performances: these are years leading to the end of a five-year term. To create better economic performances, local leaders lessen the enforcement of environmental regulations to reduce local industries' production costs and/or to attract firms from other jurisdictions. Such selective enforcement creates an environmental political business cycle in which pollution increases in years leading to the year of leader turnover. The empirical analysis on a panel of Chinese prefectures of 2002-2010 reveals a U-shaped relationship between a prefecture's party secretary's years in office and its average annual PM2.5 level.

Key words: environmental political business cycles; air pollution.

Introduction

Chinese local leaders' behaviors are driven by a career incentive structure centered on a cadre evaluation system in which those who deliver high priority targets are more likely to be promoted (Birney, 2014).[1] In recent years, new targets such as environmental protection and social stability have been added as high priorities, but promoting economic growth is still seen by many as the safest bet for career advancement (Heberer and Senz, 2011; Li and Zhou, 2005). Local leaders often signal competence when their superiors actively collect evidence to evaluate their performances: these are often the one or two years leading up to the end of the recommended five-year term. Non-compliance with environmental regulations to reduce local industries' production costs and to attract firms from other jurisdictions, we argue, is among the policy instruments used by local leaders at the end of their current tenure to create better economic performances. Such "selective policy implementation" of environmental regulations creates an environmental political business cycle in which pollution increases in years leading to local leader turnover.

We find strong empirical support in PM2.5 air pollution based on a panel dataset of Chinese prefectures of 2002-2010. The empirical analysis reveals a U-shaped relationship between a prefecture party secretary's years in office and her prefecture's average annual PM2.5 concentration. For a recommend five-year term, the turnover year is associated with a PM level that is 0.57 micrograms per cubic meter ($\mu g/m^3$) higher than mid-term years – a 2%

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[1] There is an ongoing debate regarding this performances-based model: e.g., Shih et al. (2012) argue that political connections affect promotion.

increase over the mean PM2.5 level in Chinese prefectures (about 30 μg/m^3) or a 6% increase over the World Health Organization guideline (10 μg/m^3).[2]

This paper first contributes to the political business cycle literature. Building on past research (Guo, 2009), we move away from the usual focus – government expenditures driven by electoral cycles – and study a cycle in the enforcement of environmental regulations driven by the career incentive structure in the Chinese cadre evaluation system. Second, it contributes to the literature on career incentives (Caldeira, 2012) by showing that career incentives of local officials also affect the environment.[3] Third, we advance the environmental politics literature by providing a political economic explanation of pollution at a subnational level and in authoritarian states. The environmental politics literature examines variation within democracies regarding institutional factors such as electoral rules and corporatism (Binder and Neumayer, 2005). The authoritarian environmentalism literature stresses that authoritarian leaders have an advantage in compelling businesses and citizens to comply with stringent environmental regulation (Beeson, 2010). Our findings show that due to political business cycles, local implementers in China do not follow a linear pattern. Instead, they have strong incentives to lessen the enforcement of regulations at the *right* moment to promote economic growth.

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[2] The guideline represents the lower end of the range over which one observes significant effects on survival (Pope III et al., 2002).

[3] Our theoretical intuition is similar to Shen (2016), which studies career-incentive cycles in Chinese prefecture-level GDP and air pollution.

Fourth, this paper provide a comprehensive explanation for local PM2.5 in China. Though our theoretical focus is on the environmental political business cycle, other empirical findings have profound policy implications. We find that the Environmental Kuznets Curve does not exist for PM2.5 in China, suggesting that waiting for things to improve without effective government interventions is not a promising strategy. We find coal production drives PM levels significantly: a top-10 coal sale prefecture is associated with PM2.5 level almost 30% higher than other prefectures. Finally, this paper highlights the use of non-government data in the study of Chinese politics. Official data from China is often subject to manipulation (Wallace, 2016), including pollution data (Ghanem and Zhang, 2014). Our empirical analysis uses satellite data from the National Aeronautics and Space Administration (NASA), avoiding the problem of possible data manipulation.

Political Business Cycle and its Environmental Impacts

Political Business Cycles in Local Context: political business cycles are driven by elections in democracies as office-seeking governments pursue expansionary monetary and fiscal policies before and during election years in order to win elections (Alt and Lassen, 2006). Recent studies have discovered political business cycles not only in established democracies, but also in countries going through democratic transitions and even in countries considered established autocracies (Drazen, 2000).

For authoritarian states such as China, Guo (2009) argues that county-level party secretaries accelerate government spending at the crucial point in the career path when the party committees at upper levels are about to make personnel decisions. He finds an inversed U-shaped relationship between local government expenditure growth and cadre's year in

office: expenditure peaks at the third or fourth year given a five term. This is an important contribution because it shows that political business cycles exist without competitive elections: the desire to signal competence to their superiors also make local leaders strategically allocate limited resources to display their achievement at the most optimal time of their tenures.

Incentive structures matter for political actors. In the Chinese context, recent studies focus on career incentive built in the cadre evaluation system. This approach is often called the political tournaments theory. Borrowing the theory of yardstick competition from organization economics, several scholars have proposed this to explain economic growth in China (Chen et al., 2005; Li and Zhou, 2005). Local cadres compete in a tournament-style with their counterparts in neighboring districts over promotions to the next level.[4] To maximize chances of promotion, they are motivated to develop local economies because the upper-level government makes promotion decisions by evaluating the performance of local officials based on the relative economic growth of jurisdictions (Maskin et al., 2000).

The political tournaments theory has received criticisms. For instance, the economic performance of local leaders is endogenous. Some officials with certain characteristics (e.g.,

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[4] Not all government officials are responsive to such incentives (Gao, 2017; Kou and Tsai, 2014). E.g., prefecture party secretaries' mandatory retirement age is 60; those too close to 60 might perceive themselves as non-promotable, having little incentive to perform. We experimented with adding variables to capture age effect: prefecture party secretary's age, its square term, and dummy variables indicating whether a leader is older than an age threshold (between 55 and 60). None of these variables is statistically significant.

close ties to top leaders) are assigned to provinces with greater potentials of economic growth (Jia et al., 2015). Holmstrom and Milgrom (1991) suggest that tournament systems may break down with multiple tasks. Unless these competing policy priorities are incorporated into a single, comprehensive index, promotion-oriented officials will engage in "selective implementation" of national initiatives and focus their efforts on what they perceive to be the implicit priorities of their superiors (O'Brien and Li, 1999).[5]

The political tournaments theory is built on some crucial assumptions. First, upper governments give priority to economic growth. Second, political promotion depends on local leaders' ability to grow the economy. Finally, upper governments can gain accurate measurements of local leaders' ability by observing relative GDP growth after taking into account many exogenous shocks and factor endowments.

We need to modify the final assumption if we were to observe political business cycles. If upper-level governments are able to get access to 100% information and have sufficient time and resources to evaluate every lower government's performance during an "anticipated" five-year term, the timing for a local government to exert efforts should not matter. In other words, their superior only cares and evaluates the overall economic performances over a five-year term. However, the political business cycles thesis emphasizes that a local government should exert efforts when it is optimal to impress its superior simply,

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[5] While environmental targets are substantially more important now, they compete for space on an already crowded agenda of local officials. Many local officials continue to maximize growth because they know too few cases where local leaders were promoted because of their better achievements in environmental protection (Interview, May 2012, Hunan province).

because in the real world, upper-level government officials do not have sufficient time, resources, and information to make such objective estimates. Meanwhile, like voters in elections, they are likely to discount past performances because current performances are much more visible to them.

In a democracy, the incumbent signals competence to voters right before the election when the voters are paying attention (Alt and Lassen, 2006). If we can assume that the Chinese cadre system is also characterized by incomplete information and/or that the superiors discount past economic performances, local officials should rationally produce political business cycles to signal competence when higher-level party committee members are looking for signals of competence.[6] According to Guo (2009), rapid growth in government spending on large development projects is costly and may be unsustainable. Local leaders have to schedule carefully such periods of high performance at crucial moments during their time in office: it would be unwise to increase government spending too fast in a leader's first year in office, because a promotion is unlikely to happen so early and such effort is likely to be wasted. At the same time, increasing government efforts only at the year of turnover would be too late for the effects to be visible to the superiors. The optional time to perform to impress higher-up leaders should be the years leading to the turnover year.

Environmental Impacts of Political Business Cycles: we expect that somewhere close to the turnover year, leaders are most motivated to perform. Increasing local GDP and investing in

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[6] Decisions are made by Party's organization department, which makes a recommendation to the Party committee members. See Lee (2013) for details on party leader selection.

visible "political achievement projects" often have the highest short-term payoff. Policy instruments to achieve these goals are often through increasing local government expenditures, for example, by investing in infrastructures.

Such investment projects often have negative environmental impacts. For instance, building and using roads are often associated with more air pollution. Moreover, increased local GDP as a function of local government expenditures will increase total pollution because of the scale effect. Pollution caused by infrastructure development and by increasing size of the economy is difficult to avoid for developing countries. (Empirically, we control for these two mechanisms by including variables such as road area size and GDP growth rate.) Our focus is on whether local governments use other instruments with observable environmental impacts.

Environmental regulations and their enforcements are important policy instruments. In the Chinese context, many environmental laws and regulations are designed at the central level. Their implementation, on the other hand, is largely in the hands of local leaders.[7] It is the implementation of existing laws and regulations that can be manipulated by local officials. For instance, in 2013, the State Council approved the Action Plan for Air Pollution Prevention and Control, which outlines specific PM2.5 air pollution targets for local governments to follow, but local governments have significant leeway in selecting an

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[7] Local environmental regulations exist. However, a change in local regulation has to go through the local People's Congress and People's Political Consultative Conference. Moreover, environmental regulations only get stricter over time. It is unlikely that local governments would lessen environmental regulations by creating new, less stringent laws.

implementation approach to meet these targets. Cai et al. (2016) show that local governments can affect the stringency of enforcement via the collection of pollution fees and the inspection of violations.

Lessening or non-compliance with existing regulations lowers firms' production costs. In the US context, Tobey (1990) shows that for the most pollution intensive industries, abatement costs account for 2-3% of the total production costs. In the Chinese context, Dasgupta et al. (2001a) show that for a small paper factory that on average discharges 327,800 tons of wastewater yearly, the cost of reducing 90% suspended solids alone is $452,364 in 1994. Moreover, if firms are mobile, jurisdictions with lower de facto environmental regulations attract pollution intensive firms. This is the pollution haven hypothesis, which has received empirical support in the Chinese context (Dean et al., 2009). For instance, Zhu et al. (2014) find that Chinese pollution-intensive firms have relocated from the coastal province Zhejiang to inland China, where enforcement of environmental regulation is laxer.

In the Chinese context, there are many anecdotal cases to support the trade-off between economic growth and enforcement of environmental regulations. For instance, triggered by national pressures to lower pollution, provincial leaders in Shanxi province began to reduce coal production and closed many private coalmines and coke washing companies in 2008 and 2009. As a result, GDP growth dramatically dropped to only 4%, making Shanxi one of the slowest growing provinces in China. Responding to this economic crisis, in 2010 provincial leaders reversed their green growth strategy and started to reopen some of the coalmines and to approve new coal projects (Author, 2010; The Economist, 2015).

Legal scholars have pointed out that the Chinese environmental legislation on paper is plentiful and powerful; the problem is local enforcement (Van Rooij, 2006). For instance, despite central government's efforts to clean up, the Huai River remains one of the most polluted rivers in China. Many believe that one fundamental reason is the fact that polluting factories along the river contribute significantly to local economy; local officials had strong incentives not to (fully) enforce environmental regulations (Economy, 2004).

However, there are also costs associated with environmental degradation. For instance, severe pollution can cause local political unrest (Steinhardt and Wu, 2016), which often threatens the future career of responsible officials: social stability is one of the veto targets in China for local officials. Therefore, local leaders need to take into account potential political risks associated with severe and visible pollution. This is the reason why the instrument of manipulating environmental regulation enforcement to trade environmental quality for economic growth should only be used when it matters the most for the future career of the local leaders. Based on our previous discussion on the political business cycles in China, these are the years leading to a cadre's year of turnover. Therefore, we expect to see an environmental political business cycle in which years leading to the formal turnover year of prefecture party secretaries are associated with more pollution.

Data

Dependent Variable: there is significant within-province variation in air pollution in China (Figure 1(b)), which motivates us to focus on prefecture-level differences.[8] Our dependent variable, *PM2.5*, is the prefecture annual average concentration levels of particulate matter of 2.5 micrometers or smaller, measured in micrograms per cubic meter. We use the Annual PM2.5 Grids dataset from the NASA,[9] which are grid-cells with 0.5 × 0.5 decimal degree resolution (55km by 55km at the Equator): see 2001 data of China in Figure 1(a). We re-sampled the grid-cells in ArcMap by evenly dividing each grid into 100 smaller grids; we overlaid the resampled grids to prefecture polygons of China, taking the average PM2.5 concentration levels of all resampled grids falling within a prefecture polygon.

PM is a complex mixture with extremely small particles and liquid droplets including combustion particles, organic compounds, and metals. Because fine particles (PM2.5) are much smaller than inhalable coarse particles (PM10), their negative effects on human health are much more severe. Exposure to PM2.5 is associated with premature death and increased morbidity from respiratory and cardiovascular disease (Pui et al., 2014). Recently, PM2.5 has drawn global public attention thanks to controversial events such as the US Beijing embassy's publication of Beijing local PM2.5 levels through its own monitoring system. Figure 1(b) shows that the areas with highest levels of PM2.5 concentrations are in the

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[8] Counties, especially those of east China, are often small and we simply do not see much variation in annual average air pollution among neighbouring counties.

[9] http://sedac.ciesin.columbia.edu/data/set/sdei-global-annual-avg-pm2-5-2001-2010, accessed July 2013.

southern North China Plain, along the lower Yellow River, namely southern Hebei, western Shandong, and northern Henan provinces.

In China, fine particulates are mostly from vehicle and industrial combustion emissions (Guan et al., 2014). The fact that its major sources are economic activities such as electricity generation and industrial production makes PM2.5 a good measure for our study because government environmental regulations can affect such economic activities' environmental impacts. Increased enforcement effort can lead to better environmental quality. Surveying studies on the US, Gray and Shimshack (2011) reveal that environmental monitoring and enforcement reduce future violations at targeted and non-targeted firms. Laplante and Rilstone (1996) find that government inspections reduced water pollution by 28% in 47 Canadian pulp and paper mills. Dasgupta et al. (2001b) show that state inspections of manufacturing facilities in the Zhenjiang province reduced water pollution by 0.4 to 1.2%.

Figure 1.

Explanatory Variables: a party secretary is higher in rank than a mayor is and is the primary decision-maker when it comes to salient policies.[10] Therefore, we focus on party secretary

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[10] Author (2014): "Within the leadership group, party secretaries usually hold the pre-eminent position and are seen as the first hand, while mayors are, ordinarily, the second hand and subordinate to the Party secretaries."

characteristics.[11] We first construct a dummy variable *year before turnover.* For a party secretary who did not serve more than one term, this variable takes the value 1 for the year before his/her *actual* political turnover; and 0 otherwise. For a leader who went on for a second term – of the 600 party secretaries in our data, 100 served more than one term – we also code the 5th year in office as the year before turnover (therefore taking the value of 1): the constitutionally stipulated term for a party secretary is five years; the 6th year would be the turnover year or the 1st year of the second term.[12]

Moreover, we follow a more conventional way of testing political business cycles, using a variable measuring a leader' years in office (*years in office*) and its square term (*years in office ^{2}*) to test a U shaped relationship between years in office and air pollution. We code the variable as "1" for the first year in office, "2" for the second year in office, and so on. Since some party secretaries stayed two terms in office, we expect that there will be two political business cycles for them: the cycle repeats during the second term. Thus, if one serves a second term, we recode the 6th to 10th year in office to be 1 to 5 again.

We also include a dummy variable *second term* indicating the second term of a party secretary – those who stay in office for two terms might have stronger desire to signal competence to superiors to get promotion. As stipulated in the Temporary Provisions on the Tenure of Leading Officials of the Party and the Government (2006), cadres who stay 15 years at the same level will not be considered for positions at the same level. Interviews with

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[11] The majority of biographies are from municipal government websites; remaining ones are from the Internet.

[12] See Clause 106 of the "Constitution of the People's Republic of China".

local officials from Author (2014) further reveal an informal rule that after two full terms, one cannot take the same job again.

Control Variables: we control for two other leader characteristics. *prov connect* is a dummy variable indicating whether the party secretary has connections in the provincial government: 1 if he/she had worked in provincial government before; 0 otherwise. Cadres with provincial connections may be able to better circumvent environment regulations. *SOE experience* indicates whether the party secretary had worked in state-owned enterprises previously. Cadres with SOE experience may be more development-oriented and likely to ignore environment regulations.

We include a prefecture's *GDP per capita* (inflation-adjusted) and *GDP per cap^2*: they test the Environmental Kuznets Curve – pollution increases with development first, reaching the highest point before going down. We control for GDP *growth rate* (in percentage). Furthermore, *pop density* is population density in persons per square kilometer. We include *FDI per cap* to control the effects of globalization (Zeng and Eastin, 2007). The variable *urban* (ratio of non-agricultural to the whole population) measures the level of urbanization. To control for the effects of infrastructure building, we use *road per cap, which* is the size of paved road per person in a prefecture-year (in square meters).[13]

The surge in passenger cars is one key factor for air pollution in China (Westerdahl et al., 2009). Data on private cars and means of public transportation at the prefecture level are

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[13] We also standardize the road variable by city area size. The new variable is not statistically significant.

not available. What we have is *taxi per cap*: the number of taxis per ten thousand population in a prefecture-year.[14] Taxi is a substitute for private cars. Everything else equal, more taxi usage should reduce private car demands.[15]

Coal is the most important fossil fuel for China. Data on coal production/consumption are not available at the prefecture level. The only source available is a list of top 10 coal sale prefectures (China Data Online). Thus, we construct a dummy variable indicating *top 10 coal sale* status. Moreover, power plants are an important source of air pollution. The Carma Project (http://carma.org/plant) provides probably the most comprehensive list of power plants in China. The estimation of carbon emission from Carma is not accurate enough outside the US (Afsah and Ness, 2008). Therefore, we count the *number of power plants* within a prefecture. This is a time-invariant variable because Carma has no information on years of operation.

We include *dist to Beijing* (distance to Beijing) and *dist to prov cap* (to the provincial capital), in kilometers. Closer distance to the center might incentivize local leaders to signal competence to their superiors because their efforts have a higher chance to be noticed by central/provincial governments. More efforts in visible projects, and to maximize GDP growth in general, can result in environmental degradation. Finally, we control for the effects of elevation because particulates tend to sink to the bottom. *elevation* is the average elevation

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[14] The number of unlicensed taxis is not captured by this variable.

[15] Data on GDP per capita, growth rate, population density, FDI, urbanization, road density, and taxi are from China Economic Information Network and China City Statistical Yearbook.

of a prefecture, in meters above sea level.[16] Summary and correlation statistics are in Table A-1/A-2 of online appendices.

Statistical Results

We model prefecture level annual average PM2.5 concentrations in Chinese prefectures, 2002-2010,[17] as a function of political business cycle variables and a battery of control variables. We use both random- and fixed-prefecture effects models. Fixed effects model is a conservative strategy when there is a possibility of estimation bias due to uncontrolled factors correlated with independent variables. In our case, the number of units (prefectures) is large: one has to estimate a very large number of parameters. We also have a few time-invariant variables: fixed-effects model does not allow to test the effect associated with these variables. Therefore, we exclude these variables in model specifications 5-8 (fixed effects models) in Table 1. Random (prefecture) effects model (specifications 1-4) is more efficient, but it is based on the assumption that random effects are uncorrelated with the regressors.

We use year-fixed effects in all models to control for common shocks. In model specifications 1, 3, 5, and 7, we use clustered standard error (clustered on prefectures) that estimate standard errors robust to heteroskedasticity and within-group correlation; the latter, in the panel data context, would normally mean within-panel serial correlation. In model specifications 2, 4, 6, and 8, we instead specify the within-panel serial correlation as an AR1 process.

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[16] The elevation raster data is from http://www.diva-gis.org/gdata.

[17] We do not include 2001 because GDP growth rate data is missing for 2001.

Table 1.

Effects of Environmental Political Business Cycle Variables: Table 1 shows the results of the

models with the *before turnover year* and *years in office* variables. Both are statistically

significant across all specifications. Regarding substantive effects, the mean coefficient

estimates are similar across model specifications. Using model 6, the mean coefficient

estimate is around 0.44 for the *year before turnover* variable. This suggests that the year

before leadership turnover experienced a PM2.5 level 0.44 micrograms per cubic meter

higher than other years. Holding all other variables at their mean levels, the predicted PM2.5

level is 33.6 micrograms per cubic meter, which is very close to the mean PM level from the

data. This suggests that the year before turnover experienced about 1.5% increase in PM2.5

compared to other years. This is based on the alarmingly high PM pollution in China. The

WHO and EPA guidelines are only 10 and 12 micrograms per cubic meter. For these

baselines, a 0.44 increase is an even more important change in air pollution.

The more conventional way to test a political business cycle is to include years in office

and its square term. In all four model specifications (3, 4, 7, and 8), the signs and mean

coefficient estimates of *years in office* and *years in office*^{2} suggest a U-shaped relationship

between leaders' years in office and PM2.5, with the lowest PM level around the third year in

office and the highest levels in the last year (year before turnover) and the turnover year.

There is often some time lag between the year that a leader decides to lessen environmental

regulations and the year in which one observes actual PM increase. It seems that a leader

starts the process of changing implementation about halfway through their tenure, which is

reflected in increasing levels of PM pollution starting around the fourth year; the leader

continues such "efforts" till the last year in office; the environmental impacts of such efforts

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linger on until the turnover year (the first year of the next term). In terms of the substantive effect, the difference between year 5 (the year before the turnover) and year 3 is about 0.48 – a 1.6% increase over mean PM2.5 level.

The *second term* variable also has a statistically significant and substantively important effect. Using model specification 6 again, everything else equal, years in a party secretary's second term are on average associated with a PM level 0.8 micrograms per cubic meter higher than first term years. This translates into about 2.5% of the average PM level. It seems that leaders in the second term are indeed under more pressure to signal competence for promotion because chances of staying in the same post for a third term are slim.

Figure 2.

In Figure 2, we simulate the combined effect of the *years in office*, *years in office*^{2} and *second term* variables based on specification 8 in Table 1. Holding other variables at their mean levels, we simulate the predicted levels of PM as a function of a party secretary's year in office, that is, from year 1 to year 5, and whether she/he is in the second term. For each of the other nine years included in the two terms, we calculate the *differences* in the predicted PM levels *from* the first year of the first five-year term; we plot the 90% confidence intervals of these differences, by vertical gray lines, and the mean predicted differences, by solid dark dots. (The difference of predicted PM level of the first year of the first term from itself is zero; therefore, we plot a single dot with no confidence interval for this year.) We see two clear U-shaped patterns: these are two environmental political business cycles with the second cycle associated with higher PM levels thanks to the effect of the *second term* variable. Moreover, the difference between the 5th year in the second term and the third year

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in the first term is substantively important: 1.5 micrograms per cubic meter, or 5% of the average PM level.

One might question whether prefecture party secretary tenure variables simply pick up the effects of other time-varying confounding factors such as economic plans at the national level, provincial-level leadership tenure, or even county-level leader appointments. We use year-fixed effects in all model specifications to control for national trends, common shocks, and influences of common central policies. For provincial leader cycles, we created three provincial party secretary tenure variables following the same rules coding prefecture party secretary variables. It turns out that prefecture party secretary tenure variables do not correlated with their provincial counterparts: the correlations are 0.044, 0.005, and 0.023 respectively for the *turnover year*, *years in office*, and *second term* variables.[18] Finally, coding county leader tenure variables for more than 2000 counties is beyond the scope of this paper. We do, however, have some anecdotal evidence that county cycles do not correlate with prefecture ones. For instance, in a study of the Xiaoyi County of the Shanxi province, Author (2013) find that county leader appointments simply do not coincide with their prefecture superiors'.

Effects of Control Variables: Table 1 shows that provincial connection and SOE working experience do not affect PM levels. We do not find evidence for an Environmental Kuznets Curve (EKC), which resonates with recent studies (Arvin and Lew, 2011). Neither GDP growth rate nor road density affects PM levels. With the same level of pollution intensity,

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[18] Including provincial party secretary variables does not change our main results.

increased output should increase pollution. The fact that we find no connection between growth and pollution suggests that Chinese prefectures have decreased pollution intensity.[19] At the same time, the statistical significance for the urbanization variable varies by model specifications. Furthermore, we find no evidence associating per capita FDI inflows with PM2.5.

Distance matters: the further away a prefecture is from Beijing and from its provincial capital, the lower the PM level. The other two time-invariant variables also affect PM level. Elevation matters as expected. Top 10 coal sale prefectures are on average associated with between 8.5 and 8.7 more micrograms per cubic meter PM2.5, which translates into a 28-29% increase in the mean PM level.

We find no connection between the number of power plants and PM levels. This is not surprising given we do not have information on plant size and the type of fuel used. We find that the number of taxis (per ten thousand population) is negatively associated with PM2.5. Holding all variables at the mean level, increasing the taxi variable by one standard deviation from the mean, PM2.5 decreases by about 3% from the mean.[20]

Potential spatial spill-over effects of air pollution – pollutants move with wind from one

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[19] The effect of GDP growth might have a long-lasting effect: building a new expressway might drive up long-term air pollution even though growth slows down in following years. In online appendix (Table A-3), we lag GDP growth by a year. The lagged variable is not consistently statistically significant.

[20] We have more robustness checks in online appendix: e.g., see Table A-4/A-5. The newly included variables do not affect PM levels; estimates on other variables do not change.

location to another – can be controlled by adding a spatial lag (e.g., the weighted average value of the dependent variable in "neighboring" units) and estimating using spatial models. Empirically, it is almost impossible to figure out prevailing wind directions for all Chinese prefectures as wind directions often change over seasons. More importantly, even if the underlying data generating process is a spatial lag model – one prefecture's annual average PM level is affected by those of adjacent up-wind prefectures – and the covariates of interest (political business cycle variables) are uncorrelated with the spatial lag (that is, adjacent up-wind prefectures' PM levels),[21] the estimates of coefficients of the political business cycle variables contain both the direct effect and the spatial feedback effect (Franzese and Hays, 2007). The spatial feedback effects can be interpreted as follows: an environmental business cycle affects prefecture i's PM levels, which affect its neighboring prefectures' PM levels, which in turn affect back i's PM levels, most likely as wind directions change over seasons. This actually works in our favor because we care about not only the short-term, direct effect, but also long-term feedback effects associated with career incentive variables.[22]

Conclusion

Our theory predicts an environmental political business cycle in Chinese local governance. We find empirical support in PM2.5 – a U-shaped relationship between a leader's years in

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[21] It is unlikely that a local leader' tenure correlates with neighbor prefectures' pollution.

[22] If a covariate is spatially clustered, one gets an additional bias in coefficient estimate. Using Moran's I tests, we found that none of the career incentive variables are spatially clustered.

office and air pollution. This finding suggests that local leaders behave cyclically in China. Before the promotion to the next job, they tend to be laxer in enforcing environmental standards. Once a local leader moves on to a new post, she/he is also no longer held responsible for previous actions. This inability to hold cadres responsible for environmental damage prompted a central government call for "lifetime accountability" for cadres. In 2015, the State Council approved the inclusion of such a lifetime accountability rule for environmental pollution in the new "Guidelines of Pushing the Construction of Eco-Civilization."[23] Yet, whether such a rule can be effectively enforced remains to be seen. Indeed, significant changes happened after 2010. E.g., in 2013, the central government launched the "war against air pollution." Environmental targets were included in the revised 2014 Environmental Protection Law for county-level evaluations and above.[24] Whether such changes weaken environmental political business cycles discovered for the 2002-2010 period is an important future research question.

In addition to the politics of political business cycles, there are other potential political explanations for local pollution in China. First, local interest groups might play important roles and one should look at pollution intensive industries and their abilities to lobby the government. One recent study shows that in China, cities dominated by large industrial firms

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[23] http://www.rfa.org/english/commentaries/energy_watch/officials-feel-pollution-pressure-05262015111624.html, accessed May 8, 2018.

[24] Failures to reach PM2.5 targets can result in punishments, see, http://www.chinadaily.com.cn/a/201805/25/WS5b07d05ba31001b82571c5a1.html, accessed June 15, 2018.

lagged in implementing environmental transparency, and this effect appears strongest when a city's largest firm is in a highly polluting industry (Lorentzen et al., 2014). Moreover, Fisman and Wang (2015) provide suggestive evidence that political connections enable firms to avoid costly safety compliance measures.

Finally, another framework that we might be able to follow is Author and colleagues 2014 in which they show that at the national level, authoritarian governments with stronger state capacity are associated with higher pollution because they invest more in infrastructure (that often generates pollution) than in environmental protection. Whether this holds at the subnational level needs to be tested. We have seen some preliminary evidence. For instance, Wu et al. (2013) show that there is significant gap between infrastructure and environmental investments in Chinese cities; yet they do not show whether such gap varies as a function of local government state capacity. While more research is needed to better understand the intricate connections between career incentives and the environment in China, we hope this paper has provided a solid foundation for this new and exciting area of research.

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Figure 1: PM2.5 Levels in China, 2001, in Grid Cells (a) and by Prefectures (b).
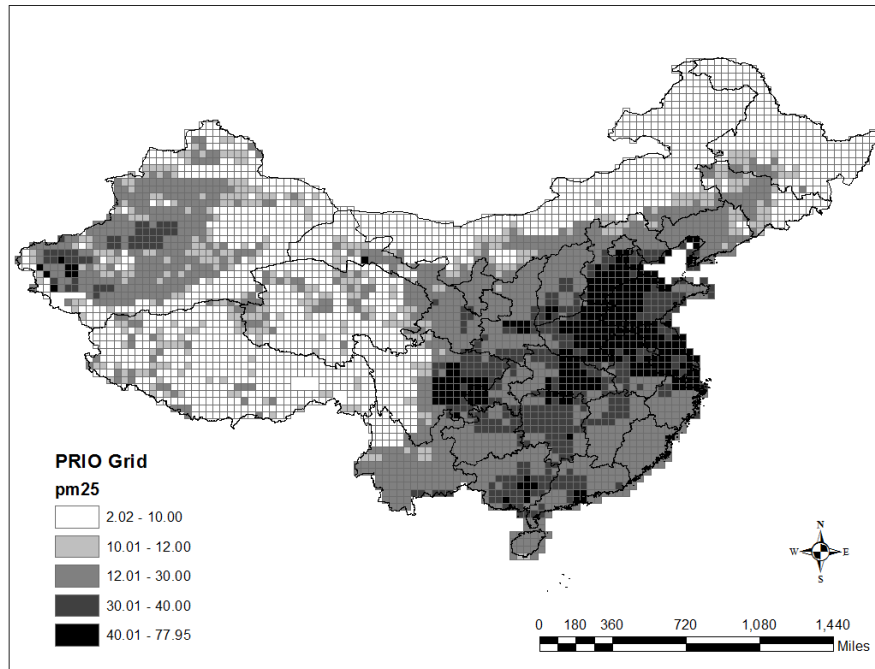
(a) PM2.5 at the original grid-cell level;
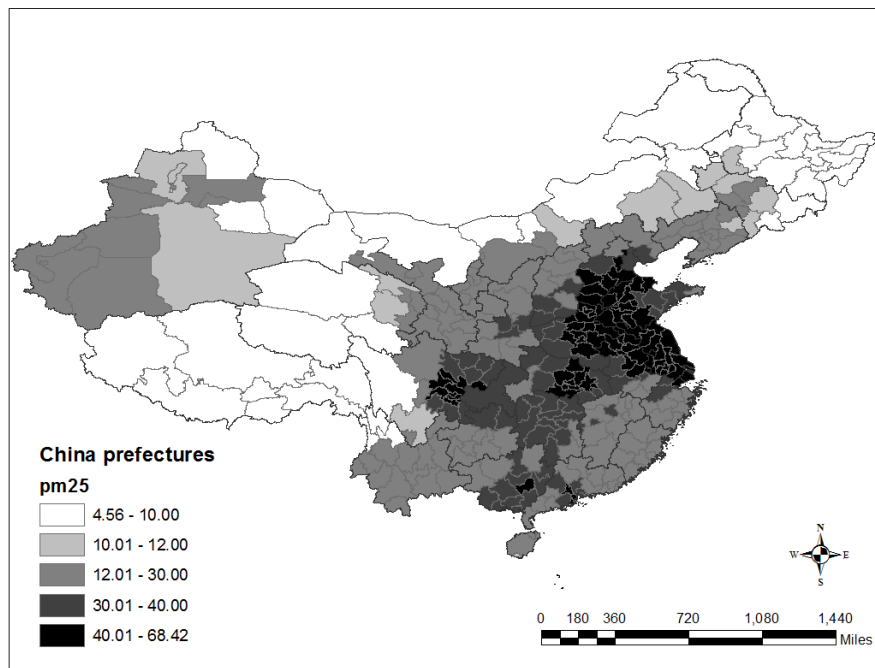
(b): prefecture level PM2.5 levels.

Figure 2: Simulated Effects of Change in PM levels from the First Year as a Function of a Party Secretary's Year in Office during Two Terms.
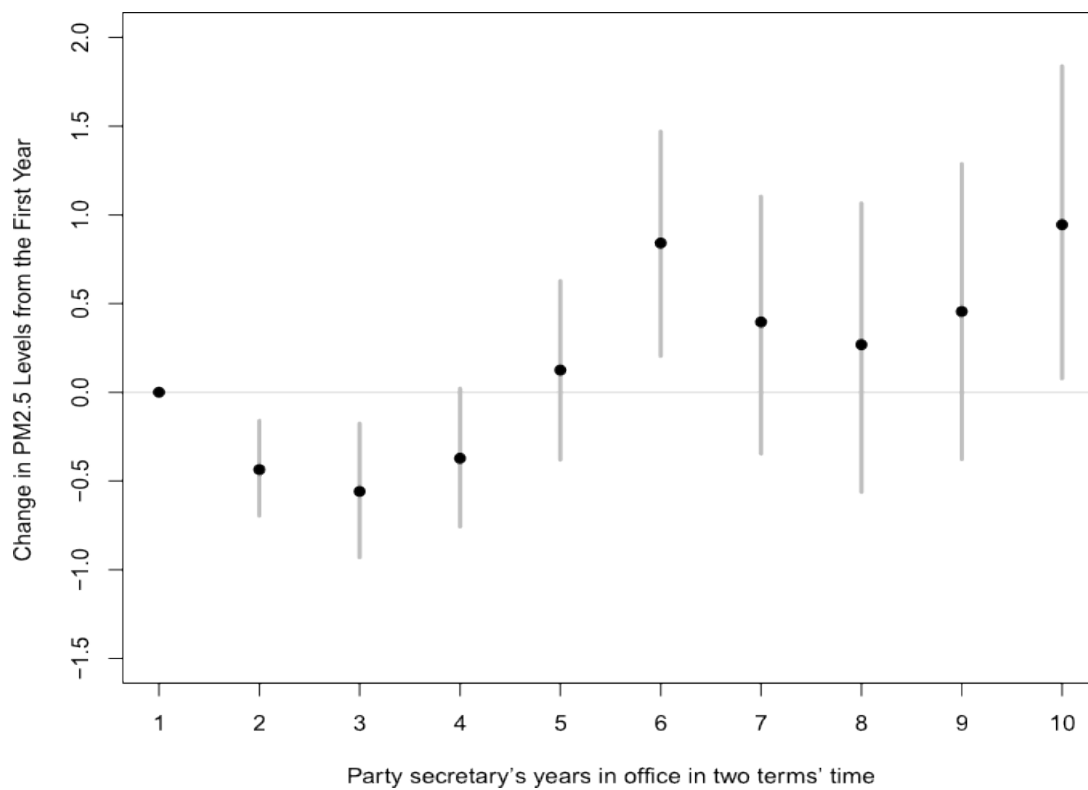
Table 1: Empirical Results from Prefecture Random and Fixed Effects Models.

	Random Effect Models				Fixed Effect Models			
	Clust. S.E.	AR1	Clust. S.E.	AR1	Clust. S.E.	AR1	Clust. S.E.	AR1
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
year before turnover	0.401**	0.411**			0.388**	0.444**		
	(0.166)	(0.196)			(0.168)	(0.198)		
years in office			-0.813***	-0.753**			-0.821***	-0.962***
			(0.293)	(0.307)			(0.295)	(0.309)
years in office^2			0.132***	0.125**			0.131**	0.158***
			(0.0504)	(0.0534)			(0.0507)	(0.0534)
second term	0.723**	0.694*	0.704*	0.723*	0.743**	0.824**	0.709*	0.834**
	(0.357)	(0.357)	(0.375)	(0.370)	(0.357)	(0.367)	(0.374)	(0.382)
prov connect	-0.150	-0.0694	-0.184	-0.106	-0.202	-0.197	-0.239	-0.225
	(0.231)	(0.273)	(0.236)	(0.274)	(0.227)	(0.303)	(0.232)	(0.303)
SOE experience	0.379	0.363	0.338	0.324	0.336	0.542	0.292	0.489
	(0.254)	(0.330)	(0.254)	(0.331)	(0.259)	(0.366)	(0.258)	(0.366)
GDP per cap	-0.420	0.443	-0.531	0.325	-0.921	4.371	-1.064	4.061
	(3.446)	(4.652)	(3.529)	(4.656)	(3.258)	(5.838)	(3.343)	(5.832)
GDP per cap^2	-0.0088	-0.0567	-0.0045	-0.0520	0.0283	-0.246	0.0339	-0.231
	(0.167)	(0.229)	(0.171)	(0.229)	(0.158)	(0.284)	(0.162)	(0.283)
pop density	-0.212	0.0556	-0.191	0.0745	-0.476**	-0.659**	-0.458**	-0.672**
	(0.157)	(0.249)	(0.161)	(0.249)	(0.207)	(0.294)	(0.217)	(0.294)
FDI per cap	-0.0179	-0.0072	-0.0375	-0.0267	-0.0145	0.0471	-0.0355	0.0197
	(0.0900)	(0.114)	(0.0902)	(0.115)	(0.0866)	(0.122)	(0.0871)	(0.122)
growth rate	0.0142	0.0059	0.0174	0.0092	0.0181	0.0127	0.0216	0.0169
	(0.0248)	(0.0246)	(0.0250)	(0.0247)	(0.0250)	(0.0258)	(0.0252)	(0.0258)
road per cap	0.0052	0.0134	0.0083	0.0169	-0.0039	0.0047	-0.00079	0.0084
	(0.0260)	(0.0317)	(0.0275)	(0.0318)	(0.0245)	(0.0331)	(0.0257)	(0.0331)
urban	1.645**	1.083	1.622**	1.055	2.141***	1.383*	2.133***	1.286
	(0.718)	(0.776)	(0.731)	(0.778)	(0.695)	(0.800)	(0.709)	(0.799)
taxi per cap	-0.0466***	-0.0687***	-0.0456***	-0.0681***	-0.0228*	-0.0367**	-0.0211	-0.0343**
	(0.0129)	(0.0143)	(0.0131)	(0.0144)	(0.0132)	(0.0169)	(0.0133)	(0.0169)
dist to Beijing	-0.0031**	-0.0034***	-0.0031**	-0.0034***				
	(0.0013)	(0.0010)	(0.0013)	(0.0010)				
dist to prov cap	-0.0313***	-0.0308***	-0.0315***	-0.0310***				
	(0.0052)	(0.0040)	(0.0052)	(0.0040)				
elevation	-0.0147***	-0.0144***	-0.0147***	-0.0144***				
	(0.0013)	(0.0011)	(0.0013)	(0.0011)				
no. power plants	0.0844	0.0878	0.0860	0.0894				
	(0.0949)	(0.0770)	(0.0950)	(0.0767)				
top 10 coal sale	8.713***	8.539***	8.714***	8.533***				
	(2.901)	(2.509)	(2.893)	(2.495)				
Constant	50.64***	47.37**	52.42***	49.11**	39.19**	7.983**	41.16**	8.255**
	(18.28)	(23.67)	(18.66)	(23.69)	(16.92)	(3.607)	(17.31)	(3.630)
AR1		ϱ=0.142		ϱ=0.141		ϱ=0.142		ϱ=0.141
Fixed Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,750	1,750	1,750	1,750	1,750	1,523	1,750	1,523
No. prefectures	227	227	227	227	227	226	227	226
R^2 (within)	0.296	0.289	0.296	0.288				
R^2 (between)	0.368	0.388	0.367	0.388				
R^2 (Overall)	0.355	0.374	0.354	0.374	0.299	0.329	0.298	0.329

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; dist to Beijing, dist to prov cap, elevation, no. power plants, and top 10 coal sale are time-invariant, thus not included in fixed effects models.