The Mandarin Model of Growth*

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Abstract

After 40 years of economic reform, China has experienced rapid growth, and yet faces substantial challenges from opaque economic statistics to quickly rising financial leverage propelled by a booming shadow banking sector. This paper expands the growth model of Barro (1990) to account for these phenomena by a common force—the agency problem between the central and local governments. To motivate local governments to develop local economies, the central government has established a tournament among local governors, which in turn generates not only the intended incentive for local governments to build up local infrastructure, à la Holmstrolm (1982), but also short-termist behaviors, à la Stein (1989), in over-reporting regional output and over-leveraging regional fiscal budgets through shadow banking.

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China's economic reform started in late 1970s and has led to spectacular economic growth at an average rate of nearly 10% per year in the past 40 years. Yet, the Chinese economy is confronted by a wide range of concerns about economic and financial risks precipitated by an economic slowdown in the recent years. A recent review by Song and Xiong (2018) summarizes these concerns. The most serious one is related to the ratio of total outstanding debt (excluding central government debt) to GDP quickly rising from a modest level of 1.2 in 2008 to over 2.1 in 2015. A substantial part of the rising leverage was originated from a booming shadow banking sector, inciting great concerns about a potential debt crisis in China. Furthermore, many commentators have pointed out that the lack of reliable economic statistics makes it particularly difficult for not only foreign observers but also Chinese economists to give timely assessments of the country's economic conditions, further exacerbating the concerns about potential economic and financial risks in China.

Despite the growing demands for economists and policy makers to evaluate the economic impact and risks imposed by the Chinese economy on the rest of the world, one is yet to develop a systematic framework that accounts for China's unique economic structure—a mixed economy with the government playing a key role in an increasingly market-driven economy. In recent years, the Chinese leadership has repeatedly used the following phrase to describe its key economic principle: "*Let markets determine resource allocation in the economy, and let the government better serve the economy.*" This phrase reflects that in the foreseeable future the government will remain as a key force in the Chinese economy.

It is also important to note that China has a complex government system with the central government working along with regional governments at several levels: province, city, county, and township. As emphasized by Xu (2011) and Qian (2017), regional governments are major players in China's economic development. First, regional governments carried out over 70% of fiscal spending in China, and they are responsible for developing economic institutions and infrastructures at the regional levels, such as opening up new markets and constructing road, highway, and airports. Second, despite their autonomy in economic and fiscal issues, regional government leaders are appointed by the central government, rather than being elected by local electorate. As a key mechanism to incentivize regional leaders, the central government has established a tournament among officials across regions at the same level, promoting those achieving fast economic growth and penalizing those with poor performance. This system of fiscal federalism greatly stimulated China's economic growth by giving local officials both fiscal budgets and career incentives to develop local economies.

In this paper, we expand the growth model of Barro (1990) to incorporate the institutional structure of China's government system. Specifically, our model considers an open economy with a number of regions. In each region, the representative firm has a Cobb-Douglas production function with three factors: labor, capital, and local infrastructure. The firm hires labor from local households at a competitive wage and rents capital at a given interest rate from an open capital market. By creating more infrastructure in the region, such as road, highway, and airports, the local government can boost the productivity of the local firm. Thus, the local government faces a tradeoff in allocating its fiscal budget, which is a fixed share of local output, into its own consumption and investment on local infrastructure. As the local government does not internalize household consumption, it has a tendency to under-invest in infrastructure relative to the first-best benchmark, in which a social planner makes the infrastructure investment decision to maximize the social welfare of not only the government but also the households. This under-investment problem reflects a key agency problem between the central and local governments, which motivates the central government to establish the economic tournament among regional governors.

Our model shows that the economic tournament indeed helps to mitigate the under-investment in infrastructure. As the output from each region reflects the ability of its governor in developing the local economy, as well as the aggregate economic shock to the country and local infrastructure, the central government uses the output from all regions at the end of each period to jointly assess the ability and determine career advancement of all regional governors. As more investment on infrastructure improves regional output, the tournament generates an implicit incentive for each governor to invest in infrastructure through the so-called signal-jamming mechanism coined by Holmstrolm (1982), due to the inability of the central government to directly separate a governor's ability from his infrastructure investment in the regional output. This incentive serves as a powerful mechanism to drive China's economic growth, as highlighted by the literature on Chinese economy, e.g., Li and Zhou (2005), Xu (2011) and Qian (2017).

More interestingly, the powerful incentives induced by the tournament may also lead local governments to engage in short-termist behaviors, à la Stein (1989), which help to explain various challenges that currently confront the Chinese economy. First, despite its rather advanced information technology and sophisticated bureaucracy, China still lacks accurate and reliable statistics about its economy. As discussed by Hortacsu, Liang and Zhou (2017), China's national GDP is routinely smaller than the sum of its provincial GDPs by an amount that varies from 7 to 20 percent of the national GDP since 2000. This enormous discrepancy cannot be simply attributed to measurement errors, nor the vanity to exaggerate China's economic achievements to the outside world. Instead, our model links it to a systematic problem of how the government bureaucracy interferes with economic statistics at the regional levels. As the central government relies on regional officials to report regional economic statistics, which are, in turn, used to evaluate their own performance, the career concern would lead them to inflate regional output. Our model conveniently captures this phenomenon by making regional output in each period not directly observable by the central government. Consequently, each regional governor is incentivized by his performance tournament to inflate regional output at the expense of having to transfer a greater fraction of the regional tax revenue to the central government based on the reported output.

The tournament among regional governors also helps to explain the rising leverage across China. As discussed by Bai, Hsieh and Song (2016) and Chen, He and Liu (2017), while local governments were prohibited from directly raising debt, the central government implicitly allowed local governments to use the so-called "local government financing vehicles (LGFVs)" for obtaining bank financing to implement China's massive post-crisis stimulus in 2008-2010. Since then, LGFVs became widely used by local governments, leading to the rapidly rising leverage across China. Interestingly, even after the central government later instructed banks not to lend to LGFVs, bank lending to LGFVs migrated into shadow banking, leading to a shadow banking boom.

We further expand our model to allow each regional government to use bank loans to finance local infrastructure investment, in addition to its tax revenue. The regional governor faces a tradeoff in taking more debt to finance more infrastructure investment to take advantage of a high growth rate of regional productivity (a social motive) and to boost his personal career (a private motive), at the expense of a higher debt payment in the next period. While a certain level of debt is socially beneficial when the local productivity growth rate is sufficiently high, our model also shows that the governor's career concern can lead to excessive leverage, which has an undesirable effect of inducing large economic fluctuations, as leverage amplifies the impact of productivity shock on local infrastructure investment.

Our model also allows us to analyze how financial innovations may exacerbate the agency problem between the central and local governments. Specifically, we further introduce a shadow banking system, which allows local governments to hide their debt from being directly observed by the central government. This in turn prevents the central government from timely updating its expectation of the debt level taken by each local government, thus making the central government unable to filter out the output growth driven by aggressive leverage choice of one local governor from the relative performance evaluation of other local governors. As a result, the short-termist behavior of one governor may adversely affect the performance evaluation of other governors, which, in turn, leads to a rat race between the governors in pursuing even higher levels of leverage in their tournament. Through this mechanism, our model shows that financial innovations exacerbate local governments' short-termist behavior, leading to rising leverage through a booming shadow banking system.

Taken together, by introducing the economic tournament of regional governors into a standard growth model, we are able to develop a convenient framework to highlight the tournament competition among regional officials as a key mechanism that drives China's rapid economic growth together with a wide range of challenges currently confronting the Chinese economy. Our work is related to the growing literature on modeling the Chinese economy. The earlier literature focuses on the institutional reform that underlies China's economic growth. Lau, Qian and Roland (2000) analyze the optimality of the dual-track reform approach adopted by China in allowing private firms to co-exist and compete with state firms. The work of Maskin, Qian, and Xu (2000) is particularly close to ours as it justifies the effectiveness of the tournament competition in motivating local officials. There is also substantial empirical evidence showing that local economic performance, such as GDP growth, is significantly correlated with the advancement of local officials, e.g., Li and Zhou (2005). Building on these theoretical and empirical results, our model embeds China's institutional system into a macroeconomic framework, and further highlights various short-termist behaviors induced by the tournament competition.

Song, Storesletten and Zilibotti (2011) develop a macroeconomic model to divide the Chinese economic growth between efficient and fast-growing private firms and inefficient state firms. Their model offers important insights about how financial frictions cause banks to discriminate against the more efficient private firms, leading to a puzzling observation of a fast-growing country exporting capital to other countries. Li, Liu and Wang (2015) develop a general equilibrium model to show how state firms, despite being less efficient, managed to earn more profits than private firms by monopolizing upstream industries and extracting rent from more liberalized downstream industries. Different from the focus of these models on the interactions between state and private firms, our model analyzes the agency problem between the central and local governments and its impact on the economy.

Our paper also adds to the literature on the effects of government spending on economic growth, e.g., Barro (1990), Easterly and Rebelo (1993), and Glomm and Ravikumar (1994). This literature is mostly agnostic about the institutional structure of the government system that supports government spending and infrastructure development. In contrast, our model highlights the tournament competition among regional governments in driving infrastructure investment, as well as short-termist behaviors, which eventually aggregate to substantial macro effects at the national level.

1 The Basic Setting

We consider an economy with M regions and infinitely many periods $t = 0, 1, 2...$ We employ a standard setting of Barro (1990) with infrastructure as public goods provided by the local government in each region. In region i ($i = 1, ..., M$), the local output is determined by

$$Y_{it} = A_{it} K_{it}^{\alpha_i} L_{it}^{1-\alpha_i} G_{it}^{1-\alpha_i}$$

where A_{it} is the local productivity, K_{it} is the capital used for production, L_{it} is the local labor input, and G_{it} is infrastructure created by the local government. The parameters $\alpha_i \in (0, 1)$ and $1 - \alpha_i$ are the output shares of capital and labor, respectively. In this section, we simply assume that the local productivity A_{it} in one region is identically and independently distributed over time, without imposing any structure on the productivities across regions. From the next section on, we will specify a particular structure with a common productivity shock affecting the productivities of all regions. The infrastructure G_{it} serves as a public good that boosts the local productivity. As we will show, the regional economy displays constant return to G_{it}, a feature that resembles the endogenous growth model of Romer (1986).

1.1 Households and Firm

In region i, there are overlapping generations of households. Each generation of households live for two periods, and each individual born at t has identical preferences represented by

$$\ln(C_{it}^{t}) + \beta \ln(C_{it+1}^{t})$$

where C_{it}^{t} and C_{it+1}^{t} represent consumption chosen by the individual across his lifetime at t and $t+1$. The parameter $\beta \in (0,1)$ is the individual's time discount rate for next period's consumption. This OLG specification with logarithmic utility simplifies the household decisions, but is inconsequential to our key insight.

Each individual supplies one unit of labor when he is young, i.e., $L_{it} = 1$, at competitive wage and divide his wage income between consumption C_{it}^{t} and saving S_{it}^{t}:

$$C_{it}^{t} + S_{it}^{t} \leq (1-\tau)\, \Phi_{it} L_{it}$$

where Φ_{it} is the competitive wage and τ is the tax rate on both labor and capital income. We adopt a small open economy setting for the region so that the saving is invested at the constant gross interest rate $R > 1$ for the next period consumption:

$$C_{it+1}^{t} = (1-\tau)\, R S_{it}^{t}.$$

Throughout the paper, we consider the whole economy in the country as a small open economy with the interest rate R being exogenously given by the global market.

The standard result for log utility implies that the individual consumes a fixed fraction of his labor income in the current period and saves the rest for the next period:

$$\begin{aligned} C_{it}^{t} &= \frac{1}{1+\beta}(1-\tau)\,\Phi_{it}L_{it}, \\ S_{it}^{t} &= \frac{\beta}{1+\beta}(1-\tau)\,\Phi_{it}L_{it}. \end{aligned}$$

We assume that firms in the region are homogenous. In each period, the representative firm in the region first observes the current period productivity A_{it} and then hires capital and labor to maximize its profit:

$$\max_{\{K_{it},L_{it}\}} \ A_{it}K_{it}^{\alpha_i}L_{it}^{1-\alpha_i}G_{it}^{1-\alpha_i} - \Phi_{it}L_{it} - RK_{it}$$

where W_{it} is the competitive wage and R is the rental rate of capital, which is equal to the interest rate. Note that we assume that the tax is levied on labor and capital incomes rather than on firms.

Given the supply of labor $L_{it} = 1$, the first order condition implies that the competitive wage is determined by the marginal product of labor:

$$\Phi_{it} = (1-\alpha_i)\,A_{it}K_{it}^{\alpha_i}G_{it}^{1-\alpha_i}.$$

By equating the marginal product of capital with the rental rate of capital, we can determine the firm's optimal capital by the firm's productivity, the capital rental rate, and the local infrastructure:

$$K_{it} = \left(\frac{\alpha_i A_{it}}{R}\right)^{1/(1-\alpha_i)} G_{it}. \quad (1)$$

By substituting K_{it} back to the output and market wage, we have

$$Y_{it} = \left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it}^{1/(1-\alpha_i)}G_{it}. \quad (2)$$

The firm's optimal capital choice and output are both proportional to local infrastructure G_{it}, which is developed by the local government. Thus, the production technology of the local economy is essentially an AK technology with respect to infrastructure stock G_{it}.

Note that $\Phi_{it}L_{it} = (1-\alpha_i)\,Y_{it}$. Thus, for an individual born at time t, his current consumption and next-period consumption are both proportional to G_{it}:

$$\begin{aligned} C_{it}^{t} &= \frac{1}{1+\beta}(1-\alpha_i)(1-\tau)\,Y_{it} \\ &= \frac{1}{1+\beta}(1-\alpha_i)(1-\tau)\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it}^{1/(1-\alpha_i)}G_{it}, \end{aligned}$$

and

$$
\begin{aligned}
C_{it+1}^{t} &= \frac{\beta}{1+\beta} R\left(1-\alpha_i\right)\left(1-\tau\right)^2 Y_{it} \\
&= \frac{\beta}{1+\beta} R\left(1-\alpha_i\right)\left(1-\tau\right)^2 \left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it}^{1/(1-\alpha_i)} G_{it}.
\end{aligned}
$$

1.2 Local Government

We assume that the country adopts a system of fiscal federalism. Specifically, the local government of each region collects tax and uses the tax revenue for developing local infrastructure and funding its own consumption. For simplicity, this paper ignores the fiscal spending of the central government, except in Section 3.

The tax is collected from labor and capital income at a rate of τ. Thus, the local government's tax revenue in period t is $\tau\left(\Phi_{it} L_{it} + R K_{it}\right) = \tau Y_{it}$, which contributes to its budget at the end of period t:

$$
W_{it} = \tau Y_{it} + \left(1-\delta_G\right) G_{it}
$$

with $\delta_G \in [0,1]$ as the depreciation rate of infrastructure and $\left(1-\delta_G\right) G_{it}$ as the infrastructure stock after depreciation. This budget is used to finance the infrastructure for the following period or government consumption in the current period:

$$
G_{it+1} + E_{it}^{G} = W_{it} \tag{3}
$$

with $E_{it}^{G} > 0$ as the government consumption in period t. Note that E_{it}^{G} benefits the people in the government system but does not directly serve the households, while the infrastructure G_{it+1} serves the welfare of both government officials and household as it increases productivity in the economy.

We assume that the local government aims to maximize the following Bellman equation:

$$
V\left(W_{it}\right) = \max_{E_{it}^{G}} \; E_t\left[\gamma \ln\left(E_{it}^{G}\right) + \beta V\left(W_{it+1}\right)\right], \tag{4}
$$

subject to the budget constraint in (3). In this specification, the government only maximizes the private benefit of government consumption without caring about the welfare of the households. The government also has a log utility function for its private benefit. The parameter $\gamma > 0$ is redundant in this Bellman equation for the government choice, but serves to measure the weight assigned to the government consumption in the first-best benchmark. The expectation operation $E_t[\cdot]$ represents the conditional expectation at time t after the current-period productivity A_{it} is observed. The value function $V(W_{it})$ captures the welfare of the government officials from period t onwards with W_{it} as the state variable to capture the local government's current-period budget.

Note the following remarks on our setting: First, we allow the government to divest its infrastructure without any cost, i.e., G_{it} can be smaller than $(1-\delta_G)\,G_{it-1}$. Section, in this section, we assume that the government cannot borrow or save and must spend its budget in each period on either infrastructure investment or government consumption. We relax this assumption in Sections 4 and 5 by letting the government to use debt. Third, the government's investment decision at time t determines the level of infrastructure at $t+1$. This feature is realistic as infrastructure investment usually takes a long time. As the governor is constrained from borrowing or saving, he has to allocate his current-period budget on either infrastructure investment or government consumption, leading to an intertemporal trade-off. If he allocates more to infrastructure investment (i.e., a higher G_{it+1}), the local output and tax revenue in the next period are larger, trading off less current-period government consumption. By directly solving the Bellman equation, Proposition 1 summarizes the governor's optimal investment rule.

Proposition 1 *In each period, the local government allocates a fixed fraction β of its budget to local infrastructure:*

$$G_{it+1} = \beta\left[\tau Y_{it} + (1-\delta_G)\,G_{it}\right].$$

Because of the local government's self interest in spending the tax revenue, the infrastructure investment level is not socially optimal. For comparison, we analyze the first-best benchmark below.

1.3 The First-Best Benchmark

In our main setting, the local government is only concerned by the government consumption, but not that of the households. As a result, its infrastructure choice does not maximize the social welfare. As a benchmark, we also consider a social planner, who aims to maximize the welfare of the households, in addition to that of the local government. To facilitate our analysis of the local infrastructure choice, we maintain the same firm capital and labor choices as before and only let the social planner to make the infrastructure decision. That is, at time t, the representative firm chooses its capital after observing the local government's infrastructure choice G_{it} and the local productivity A_{it}:

$$K_{it} = \left(\frac{\alpha_i}{R}\right)^{\frac{1}{1-\alpha_i}} A_{it}^{\frac{1}{1-\alpha_i}} G_{it}$$

and offers the competitive wage:

$$\Phi_{it} = (1-\alpha_i) A_{it} K_{it}^{\alpha_i} G_{it}^{1-\alpha_i}$$

so that $L_{it} = 1$. Consequently,

$$Y_{it} = \left(\frac{\alpha_i}{R}\right)^{\frac{\alpha_i}{1-\alpha_i}} A_{it}^{\frac{1}{1-\alpha_i}} G_{it}.$$

To determine G_{it}, the social planner is not constrained by the local government's budget, and instead can allocate the aggregate social budget in the local economy

$$W_{it}^{planner} = Y_{it} + (1-\delta_G) G_{it}$$

to the young generation consumption C_{it}^{t}, the old generation consumption C_{it}^{t-1}, the government consumption E_{it}^{G}, and infrastructure G_{it+1}:

$$W_{it}^{planner} = C_{it}^{t} + C_{it}^{t-1} + E_{it}^{G} + G_{it+1}$$

to maximize

$$V\left(W_{it}^{planner}\right) = \max_{C_{it}^{t}, C_{it}^{t-1}, E_{it}^{G}, G_{it+1}} E_t\left[\ln\left(C_{it}^{t}\right) + \ln(C_{it}^{t-1}) + \gamma \ln E_{it}^{G} + \beta V\left(W_{it+1}^{planner}\right)\right]. \quad (5)$$

The following proposition states the result from solving the planner's Bellman equation:

Proposition 2 *In the first-best benchmark, the social planner allocates a fixed fraction β of the aggregate wealth to infrastructure:*

$$G_{it+1} = \beta\left[Y_{it} + (1-\delta) G_{it}\right].$$

A comparison of Propositions 1 and 2 shows that the local government under-invests in infrastructure relative to the first-best level. This is because the local government does not internalize the consumption of the household in its infrastructure choice. As a result, it allocates only a fixed fraction β of its fiscal budget, which is small than the aggregate social budget, to infrastructure. In contrast, the social planner allocates a fraction β of the social budget to infrastructure. This under-investment reveals a fundamental agency problem between the central and local governments, and motivates the central government to use the economic tournament to mitigate the agency problem.

2 Tournament of Regional Governors

Different from the typical federal government system in other countries, regional governors in China are appointed by the central government, rather than elected by local electorate. As eloquently summarized by Xu (2011) and Qian (2017), by giving local governments large fiscal independence and evaluating them based on a common set of criterions that weigh heavily on local economic performance, regional governors are greatly incentivized to become helping hands, rather than grabbing hands, in developing local economies. This economic tournament is widely recognized as a key mechanism contributing to China's rapid growth in the past 40 years.[1]

To incorporate the tournament, we adopt the following specification of the productivity of region i to examine the local governor's career concern:

$$A_{it} = e^{f_t + a_{it} + \varepsilon_{it}},$$

where $f_t \sim N\left(\bar{f}, \sigma_f^2\right)$ represents a countrywide common shock with Gaussian distribution of mean $\bar{f}$ and variance σ_f^2, $a_{it} \sim N\left(\bar{a}_i, \sigma_a^2\right)$ represents the governor's ability in developing the local economy, which has Gaussian distribution of mean $\bar{a}_i$ and variance σ_a^2, and $\varepsilon_{it} \sim$

[1] In typical western countries, career concerns of politicians who aim to win local elections may also generate incentives to develop local economies. Such incentives vary across regions depending on the preferences and interests of the local electorates. For example, voters in one region may care more about economic growth, and thus leading to greater incentives for politicials to develop local economy; while voters in another region may care more about the environment, thus leading politicals to give lower priority to developing the economy. Having the central government as the common evaluator of all regional governors in China dictates that they all share the same career incentives and thus compete directly with each other.

$N(0, \sigma_\varepsilon^2)$ is an idiosyncratic noise component again with Gaussian distribution of mean 0 and variance σ_ε^2. Neither of these components is publicly observable, but their distributions are common knowledge to all agents.

We assume that a new governor, randomly drawn from the distribution $N(\bar{a}_i, \sigma_a^2)$, is assigned to a region in each period. The governor works in the region for only one period, and is concerned of the central government's perception of his ability after observing his performance and his peers' performance. Specifically, suppose that a governor takes over region i at time t and chooses E_{it}^G and G_{it+1}. As the governor's ability affects the local productivity at $t+1$, the local output Y_{it+1} provides useful information about his ability when his term ends at $t+1$. That is, his performance is determined by

$$\widehat{a}_{it+1} = E\left[a_{it+1} | \{Y_{it+1}\}_{i=1,\dots,M}\right].$$

By substituting in Y_{it+1} from (2), we obtain

$$\begin{aligned} y_{it+1} &= \ln(Y_{it+1}) = \ln\left[\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} G_{it+1}\right] \\ &= \frac{1}{1-\alpha_i}(f_{t+1} + a_{it+1} + \varepsilon_{it+1}) + \frac{\alpha_i}{1-\alpha_i}\ln\left(\frac{\alpha_i}{R}\right) + \ln(G_{it+1}). \qquad (6) \end{aligned}$$

In deriving this expression, we have used the local labor supply $L_{it+1} = 1$ and local capital input K_{it+1} given in (1). Equation (6) shows that the local output $\ln(Y_{it+1})$ provides a useful signal about the governor's ability a_{it+1}. As the governor can boost the local output by taking on more infrastructure investment, the governor's career concern gives an incentive to invest more in infrastructure, overcoming his preference for more private consumption. The career concern thus provides an implicit incentive to invest in local infrastructure, which is in the spirit of Holmstrolm (1982) and Gibbons and Murphy (1992).

To analyze this mechanism, we assume that the central government cannot observe the stock of local infrastructure (i.e., G_{it+1}) and other input in local production. Instead, it observes only the output level Y_{it+1}. This assumption is realistic for several reasons. First, local governments in China have ample flexibility in at least temporarily hiding detailed information related to factor input in their regions. Second, the central government devotes a great effort in collecting information about the aggregate output, as it is a key variable for many policy decisions of the central government. In the next section, we will further modify the setting to make local output not directly observable by the central government.

As the central government can only observe Y_{it+1}, it relies on Y_{it+1} to infer the value of each governor's ability a_{it+1}. Following Holmstrolm (1982), we assume that the central government has rational expectations and anticipates the local governor to choose a level of infrastructure G_{it+1}, which is equal to its equilibrium level G^*_{it+1}. As a result, in interpreting the observed output, the central government would simply deduct $\ln\left(G^*_{it+1}\right)$ from the observed log output y_{it+1}, even though it does not directly observe the governor's actual choice G_{it+1}, by constructing the following sufficient statistic:

$$\begin{aligned} z_{it+1} &\equiv (1-\alpha_i)\left\{y_{it+1} - \left[\frac{\alpha_i}{1-\alpha_i}\ln\left(\frac{\alpha_i}{R}\right) + \ln\left(G^*_{it+1}\right)\right]\right\} \\ &= f_{t+1} + a_{it+1} + \varepsilon_{it+1} + (1-\alpha_i)\left[\ln\left(G_{it+1}\right) - \ln\left(G^*_{it+1}\right)\right]. \end{aligned} \tag{7}$$

From the central government's perspective, the governor would choose $G_{it+1} = G^*_{it+1}$, and consequently

$$z_{it+1} = f_{t+1} + a_{it+1} + \varepsilon_{it+1}. \tag{8}$$

Due to the common shock in each region's productivity, the central government will use the outputs from all regions to jointly infer each governor's ability. This joint evaluation leads to a tournament, in which each governor's performance is compared with that of other governors. By directly applying the Bayes Theorem based on the composition of z_{it+1} given in (8), we obtain the following learning rule for the central government:

$$\begin{aligned} \hat{a}_{it+1} &= E\left[a_{it+1} \middle| \left\{z_{it+1}\right\}_{i=1,\ldots,M}\right] \\ &= \bar{a}_i + \frac{\sigma_a^2\left(\sigma_a^2+\sigma_\varepsilon^2+(M-1)\,\sigma_f^2\right)}{\left(\sigma_a^2+\sigma_\varepsilon^2\right)\left(\sigma_a^2+\sigma_\varepsilon^2+M\sigma_f^2\right)}\left(z_{it+1}-\bar{z}_{it+1}\right) \\ &\quad - \frac{\sigma_a^2\sigma_f^2}{\left(\sigma_a^2+\sigma_\varepsilon^2\right)\left(\sigma_a^2+\sigma_\varepsilon^2+M\sigma_f^2\right)}\sum_{j\neq i}\left(z_{jt+1}-\bar{z}_{jt+1}\right). \end{aligned}$$

From the governor's perspective, z_{it+1} depends on his own choice G_{it+1} in (7). As a result, the governor can influence the central government's perception $\hat{a}_{it+1}$ by choosing a higher level of G_{it+1} at time t. By substituting in z_{it+1} from (7), we have

$$\begin{aligned} & \hat{a}_{it+1} - \bar{a}_i \\ = \; & \frac{\sigma_a^2 \left(\sigma_a^2 + \sigma_\varepsilon^2 + (M-1)\,\sigma_f^2\right)}{\left(\sigma_a^2 + \sigma_\varepsilon^2\right)\left(\sigma_a^2 + \sigma_\varepsilon^2 + M\sigma_f^2\right)} \left[\left(f_{t+1} - \bar{f}\right) + \left(a_{it+1} - \bar{a}_i\right) + \varepsilon_{it+1} + (1-\alpha_i)\left(\ln G_{it+1} - \ln G_{it+1}^*\right)\right] \\ & - \frac{\sigma_a^2 \sigma_f^2}{\left(\sigma_a^2 + \sigma_\varepsilon^2\right)\left(\sigma_a^2 + \sigma_\varepsilon^2 + M\sigma_f^2\right)} \\ & \cdot \sum_{j \neq i} \left[\left(f_{t+1} - \bar{f}\right) + \left(a_{jt+1} - \bar{a}_j\right) + \varepsilon_{jt+1} + (1-\alpha_j)\left(\ln G_{jt+1} - \ln G_{jt+1}^*\right)\right] \end{aligned} \quad (9)$$

This expression shows that choosing a higher G_{it+1} affects the central government's perception, even though the central government rationally anticipates such a behavior in equilibrium, as reflected by its anticipation of $G_{it+1} = G_{it+1}^*$. This is the basic insight of the signal-jamming mechanism highlighted by Holmstrolm (1982).

To capture the governor's career concern induced by the tournament, we introduce an additional term into the local government's Bellman equation previously specified in (4):

$$V\left(W_{it}\right) = \max_{G_{it+1}} E_t\left[\gamma \ln\left(W_{it} - G_{it+1}\right) + \chi_i\left(\hat{a}_{it+1} - \bar{a}_i\right) + \beta V\left(\tau Y_{it+1} + \left(1-\delta_G\right) G_{it+1}\right)\right] \quad (10)$$

where $\chi_i\left(\hat{a}_{it+1} - \bar{a}_i\right)$ is the new term with $\chi_i > 0$ as the weight assigned to the governor's career concern.[2] In formulating this Bellman equation, we implicitly assume that there are other local officials in the local government, who remain in the region despite the change of the governor in each period. As these local officials care about their future consumption, they will ensure that the governor's infrastructure choice account for their future consumption, as reflected by the last term in the Bellman equation.

With the additional career concern term, the relevant terms in the governor's objective for choosing G_{it+1} on the right hand side of the Bellman equation (10) are

$$\max_{G_{it+1}} E_t\left[\gamma \ln\left(W_{it} - G_{it+1}\right) + \kappa_i \ln G_{it+1} + \beta V\left(\left(1-\delta_G\right) G_{it+1} + \tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} G_{it+1}\right)\right]$$

where

$$\kappa_i = \frac{\sigma_a^2 \left(\sigma_a^2 + \sigma_\varepsilon^2 + (M-1)\,\sigma_f^2\right)}{\left(\sigma_a^2 + \sigma_\varepsilon^2\right)\left(\sigma_a^2 + \sigma_\varepsilon^2 + M\sigma_f^2\right)} \left(1-\alpha_i\right) \chi_i \quad (11)$$

[2] One may micro-found this term by assuming that the central government randomly pair each governor with another governor and promote the one with better perception. Linearing the expected promotion probability leads to the linear term specified in the objective.

These terms are almost the same as those from the Bellman equation in (4), except the additional term $\kappa_i \ln G_{it+1}$ in the first bracket due to the governor's career concern. By solving the Bellman equation, we obtain the optimal infrastructure as summarized in the next proposition:

Proposition 3 *The governor's career concern leads to greater infrastructure investment:*

$$G_{it+1} = \left[\frac{\kappa_i}{\gamma + \kappa_i} (1 - \beta) + \beta \right] (\tau Y_{it} + (1 - \delta_G) G_{it}).$$

Proposition 3 shows that the career concern motivates the governor to choose a greater level of infrastructure investment. In particular, a governor with a higher χ_i coefficient invests more into infrastructure. Thus, the tournament helps to overcome the under-investment problem to infrastructure, as derived in Proposition 1 for the case when the local government only cares about government consumption. This simple result provides the institutional foundation for China's rapid growth, building on strong career incentives for local governors to develop local economies.

The career concern not only leads to positive incentives of developing local infrastructure but also other short-termist behaviors. In the subsequent sections, we analyze such short-termist behaviors induced by the tournament.

3 Output Inflation

In this section, we analyze over-reporting of regional output induced by the career concern of local governors. To examine this issue, we modify the model setting by assuming that the central government does not directly observe the regional output in the current period. Instead, each governor reports the output of his region to the central government. This gives each governor the flexibility to inflate his performance. As a discipline of potential over-reporting, the central government takes away a fraction of the reported output as tax revenue to fund the central government spending. Thus, from the perspective of a regional governor, inflating the local output comes with the cost of a larger tax transfer to the central government.

Specifically, we assume that a governor is free to report Y'_{it} as the output of his region, which may be different from the actual output Y_{it}. Or equivalently, the governor may choose to report the log output y'_{it}, which is different from the actual log output y_{it}. Suppose that the governor chooses to inflate y'_{it} by an amount φ_{it}:

$$y'_{it} = y_{it} + \varphi_{it}.$$

With the actual output given by (6), the reported output is

$$y'_{it} = \frac{1}{1-\alpha_i}\left(f_t + a_{it} + \varepsilon_{it}\right) + \frac{\alpha_i}{1-\alpha_i}\ln\left(\frac{\alpha_i}{R}\right) + \ln\left(G_{it}\right) + \varphi_{it}.$$

In interpreting the reported output, the central government anticipates the governor to invest G^*_{it} in infrastructure and over-report by φ^*_{it} and thus constructs the following sufficient statistic:

$$\begin{aligned} z'_{it} &\equiv (1-\alpha_i)\left\{y'_{it} - \left[\frac{\alpha_i}{1-\alpha_i}\ln\left(\frac{\alpha_i}{R}\right) + \ln\left(G^*_{it}\right)\right] - \varphi^*_{it}\right\} \\ &= f_t + a_{it} + \varepsilon_{it} + (1-\alpha_i)\left[\ln\left(G_{it}\right) - \ln\left(G^*_{it}\right) + \left(\varphi_{it} - \varphi^*_{it}\right)\right]. \end{aligned}$$

With rational expectations, the central government expects the governor's choices $G_{it} = G^*_{it}$ and $\varphi_{it} = \varphi^*_{it}$, thus it views

$$z'_{it} = f_t + a_{it} + \varepsilon_{it}.$$

Consequently, we have the same learning rule for the central government as before:

$$\begin{aligned} &\hat{a}_{it+1} - \bar{a}_i \\ &= E\left[a_{it+1} \middle| \left\{z'_{it+1}\right\}_{i=1,\ldots,M}\right] - \bar{a}_i \\ &= \frac{\sigma_a^2\left(\sigma_a^2 + \sigma_\varepsilon^2 + (M-1)\sigma_f^2\right)}{\left(\sigma_a^2 + \sigma_\varepsilon^2\right)\left(\sigma_a^2 + \sigma_\varepsilon^2 + M\sigma_f^2\right)}\left(z'_{it+1} - \bar{z}_{it+1}\right) - \frac{\sigma_a^2\sigma_f^2}{\left(\sigma_a^2 + \sigma_\varepsilon^2\right)\left(\sigma_a^2 + \sigma_\varepsilon^2 + M\sigma_f^2\right)}\sum_{j\neq i}\left(z'_{jt+1} - \bar{z}_{jt+1}\right) \\ &= \frac{\sigma_a^2\left(\sigma_a^2 + \sigma_\varepsilon^2\right)}{\left(\sigma_a^2 + \sigma_\varepsilon^2\right)\left(\sigma_a^2 + \sigma_\varepsilon^2 + M\sigma_f^2\right)}\left(f_{t+1} - \bar{f}\right) \\ &+ \frac{\sigma_a^2\left(\sigma_a^2 + \sigma_\varepsilon^2 + (M-1)\sigma_f^2\right)}{\left(\sigma_a^2 + \sigma_\varepsilon^2\right)\left(\sigma_a^2 + \sigma_\varepsilon^2 + M\sigma_f^2\right)}\left[\left(a_{it+1} - \bar{a}_i\right) + \varepsilon_{it+1} + (1-\alpha_i)\left(\ln G_{it+1} - \ln G^*_{it+1} + \varphi_{it+1} - \varphi^*_{it+1}\right)\right] \\ &- \frac{\sigma_a^2\sigma_f^2}{\left(\sigma_a^2 + \sigma_\varepsilon^2\right)\left(\sigma_a^2 + \sigma_\varepsilon^2 + M\sigma_f^2\right)}\sum_{j\neq i}\left[\left(a_{jt+1} - \bar{a}_j\right) + \varepsilon_{jt+1} + (1-\alpha_j)\left(\ln G_{jt+1} - \ln G^*_{jt+1} + \varphi_{jt+1} - \varphi^*_{jt+1}\right)\right]. \end{aligned}$$

The central government's perception of the governor's ability $\hat{a}_{it+1} - \bar{a}_i$ is tied to his output inflation $\varphi_{it+1} - \varphi^*_{it+1}$, even though the central government anticipates him to inflate by $\varphi_{it+1} = \varphi^*_{it+1}$.

We further expand the tax system by assuming that the local government needs to transfer part of its tax revenue to the central government at a rate of $\tau_c < \tau$ based on the reported output level Y'_{it+1}. In other words, while the local government collects a tax of τY_{it+1} based on the actual output, it has to transfer a greater fraction of the tax revenue to the central government if it chooses to inflate the output. Specifically, the residual tax revenue left for the local government is

$$\begin{aligned} T_{it+1} &= \tau Y_{it+1} - \tau_c Y'_{it+1} \\ &= \tau Y_{it+1} \left(1 - \frac{\tau_c}{\tau} e^{\varphi_{it+1}}\right). \end{aligned}$$

A higher inflation φ_{it+1} thus reduces the local budget for the following period. This feature is consistent with the finding of Fan, Xiong and Zhou (2016) that during the Great Famine of China in 1959-1961 the over-reporting of regional agricutural output led to greater procurement of grain to the central government and more severe famine in the region.

We now revisit the governor's Bellman equation:

$$V(G_{it}, T_{it}) = \max_{G_{it+1},\, \varphi_{it+1}} E_t \left[\gamma \ln\left((1-\delta_G) G_{it} + T_{it} - G_{it+1}\right) + \chi_i \left(\hat{a}_{it+1} - \bar{a}_i\right) + \beta V\left(G_{it+1}, T_{it+1}\right)\right] \tag{12}$$

where we reformulate the value function as a function of G_{it} and T_{it}, rather than a function of the total budget W_{it}. This is because the potential over-reporting makes W_{it} insufficient to capture the state of the regional economy. The relevant terms in the governor's objective for choosing G_{it+1} and φ_{it+1} on the right hand side of the Bellman equation are

$$\begin{aligned} \max_{G_{it+1},\, \varphi_{it+1}} & \gamma \ln\left((1-\delta_G) G_{it} + T_{it} - G_{it+1}\right) + \kappa_i \ln\left(G_{it+1}\right) + \kappa_i \left(\varphi_{it+1} - \varphi^*_{it+1}\right) \\ & + \beta E_t \left[V\left(G_{it+1}, \tau Y_{it+1}\left(1 - \frac{\tau_c}{\tau} e^{\varphi_{it+1}}\right)\right)\right] \end{aligned}$$

The term $\kappa_i \left(\varphi_{it+1} - \varphi^*_{it+1}\right)$, with κ_i given in (11), captures the governor's incentive to boost his career by inflating the output, while the last term $\beta E_t \left[V\left(G_{it+1}, \tau Y_{it+1}\left(1 - \frac{\tau_c}{\tau} e^{\varphi_{it+1}}\right)\right)\right]$ contains the cost of leaving a smaller fiscal budget for the next period.

By solving this Bellman equation, the next proposition confirms that the governor's career concern indeed leads to over-reporting of the local output and the over-reporting increases with his career incentive κ_i and decreases with the central government tax rate τ_c.

Proposition 4 *The governor's output inflation is given by the following equation:*

$$\varphi_{it+1} = \ln \frac{(1-\beta)\,\kappa_i}{\beta\tau_c\,(\kappa_i+\gamma)} - \ln\left\{\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} E_t\left[\frac{A_{it+1}^{1/(1-\alpha_i)}}{1-\delta_G+\tau\left(1-\frac{\tau_c}{\tau}e^{\varphi_{it+1}}\right)\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)}}\right]\right\},$$

which has a unique root between 0 *and* $\ln(\tau/\tau_c)$ *under the conditions (20) and (21) listed in the appendix. This root is increasing with* κ_i *and decreasing with* τ_c*.*

The mechanism for output inflation described in this section is similar in nature to Stein (1989) for earnings manipulation by publicly listed firms. As firm managers have incentives to boost their stock prices, the signal jamming mechanism causes them to inflate firm earnings, despite that investors rationally anticipate such inflation and deduct the inflation in stock valuation. By confirming this mechanism, Proposition 4 suggests that the lack of reliable economic statistics in China is a systematic problem associated with China's government bureaucracy.

4 Excessive Leverage

So far we have restricted regional governments from using any debt to leverage their fiscal budgets. This assumption is realistic for China for the period before 2008, as the central government had strict rule against subnational governments raising debt without its explicit approval. However, the situation substantially changed after 2008, when the global financial crisis prompted China to implement a massive economic stimulus of four trillion RMB. As the stimulus was mostly financed by fiscal budgets of local governments (rather than that of the central government) and the stimulus required much more financing than what local governments could afford, the central government implicitly allowed local governments to establish the so-called "local government financing vehicles (LGFVs)", which used implicit guarantees from local governments to obtain bank loans or issue wealth management products (a form of shadow banking products) to the public. See Bai, Hsieh and Song (2016) and

Chen, He, and Liu (2017) for detailed analysis of this development. Since then, local governments have been frequently using debt from either banks or the shadow banking system to finance their spending.

Debt gives a governor greater capacity to invest in local infrastructure, and thus may exacerbate his short-termist behavior induced by the tournament competition. To address this issue, we make another extension of the model setting. Specifically, we anchor on the setting from Section 2 (without output inflation and the tax transfer to the central government), and allow each regional government to use debt to finance its infrastructure investment and spending. Specifically, we assume that it can issue debt at a constant interest rate R. Then, its budget in period t is its tax revenue from the previous period τY_{it} plus the stock of infrastructure $(1-\delta_G)\, G_{it}$ minus its debt due RD_{it-1}:

$$W_{it} = \tau Y_{it} + (1-\delta_G)\, G_{it} - RD_{it-1}.$$

The governort can take new debt D_t, in addition to W_{it}, to fund its infrastructure investment and government consumption E^G_{it}:

$$G_{it+1} + E^G_{it} = W_{it} + D_{it}.$$

We maintain the Bellman equation in (10) but give the governor the additional debt choice in each period:

$$\begin{aligned} V\left(W_{it}\right) &= \max_{G_{it+1},\, D_{it}} E_t\left[\gamma \ln E^G_{it} + \chi_i\left(\hat{a}_{it+1} - \bar{a}_i\right) + \beta V\left(\tau Y_{it+1} + (1-\delta_G)\, G_{it+1} - RD_{it}\right)\right] \\ &= \max_{G_{it+1},\, D_{it}} \gamma \ln\left(W_{it} + D_{it} - G_{it+1}\right) + \kappa_i\left(\ln G_{it+1} - \ln G^*_{it+1}\right) \qquad (13) \\ &\qquad + \beta E_t\left[V\left(\tau Y_{it+1} + (1-\delta_G)\, G_{it+1} - RD_{it}\right)\right] \end{aligned}$$

It shall be clear by now that W_{it} is sufficient to capture the state of the regional economy at time t, despite the use of debt. To facilitate our analysis, we scale the governor's infrastructure stock in each period by its budget:

$$g_{it+1} = \frac{G_{it+1}}{W_{it}},$$

and debt level by its infrastructure stock:

$$d_{it} = \frac{D_{it}}{G_{it+1}}.$$

d_{it} can be directly interpreted as the fraction of infrastructure financed by debt. As we formally derive in the Appendix, debt allows the governor to take on a higher level of infrastructure relative to its current-period budget:

$$g_{it+1} = \frac{\beta\gamma + \kappa_i}{\gamma + \kappa_i} \frac{1}{(1 - d_{it})}.$$

A certain level of debt is socially beneficial as it allows the regional government to expand its budget to fully take advantage of high productivity in the current period. However, the governor's career concern may induce excessive use of debt to finance over-investment at the expense of a higher debt payment and thus a smaller budget in the next period. To systematically examine this issue, we also examine the debt choice of a social planner who aims to maximize the welfare of both the government and the households. Following the setting in Section 1.3, the planner's budget at time t is

$$W_{it}^{planner} = Y_{it} + (1 - \delta_G) G_{it} - RD_{it-1}$$

which also includes repayment of the local government debt from the previous period. The planner can also use new debt to boost its current period budget:

$$C_{it}^{t} + C_{it}^{t-1} + E_{it}^{G} + G_{it+1} = W_{it}^{planner} + D_{it}$$

to finance infrastucture investment G_{it+1}, together with the consumption of the two generationas of households C_{it}^{t} and C_{it}^{t-1} and the government consumption E_{it}^{G}. Then, the planner's Bellman equation is given by

$$V\left(W_{it}^{planner}\right) = \max_{G_{it+1}, C_{it}^{t}, C_{it}^{t-1}, E_{it}^{G}, D_{it}} E_t \left[\ln\left(C_{it}^{t}\right) + \ln(C_{it}^{t-1}) + \gamma \ln E_{it}^{G} + \beta V\left(W_{it+1}^{planner}\right)\right]. \quad (14)$$

We directly solve the Bellman equation of both the governor in (13) and the planner in (14). Interestingly their debt choices are determined by a maximization problem with the same structure except different coefficients, as summarized in the following proposition:

Proposition 5 *To avoid default, both the governor and the social planner would choose a debt level* $d_{it} = D_{it}/G_{it+1}$ *in the interval* $[0, (1-\delta_G)/R]$, *based on the following maximization problem:*

$$\max_{d_{it}} \Psi \ln\left(\frac{1}{1 - d_{it}}\right) + E_t\left[\ln\left(\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} + (1 - \delta_G) - Rd_{it}\right)\right]$$

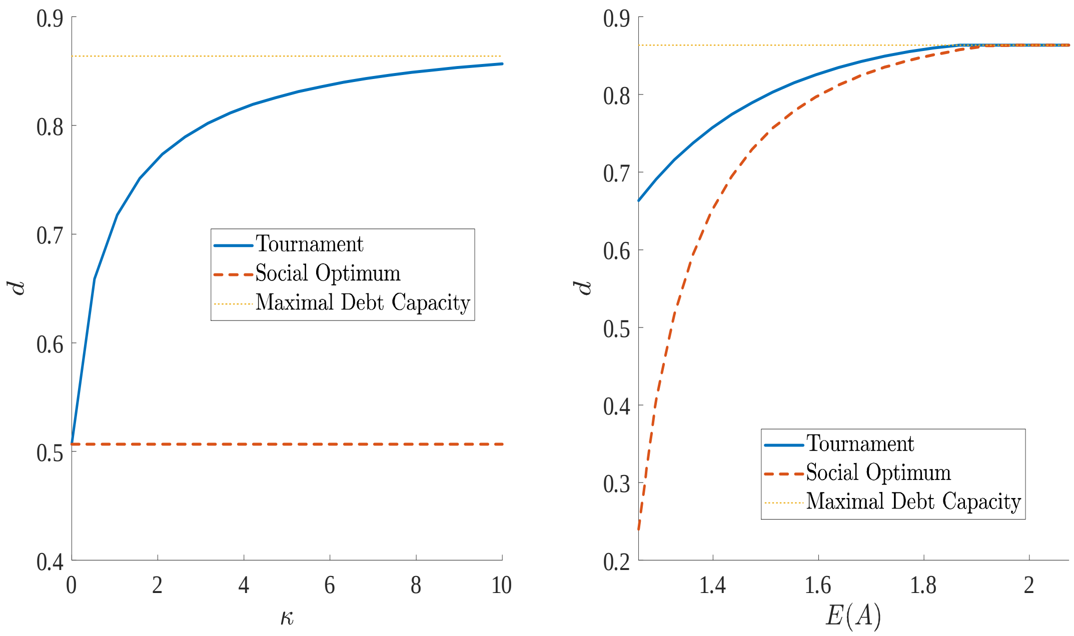

Figure 1: Leverage with Career Incentive and Expected Growth

where the coefficient Ψ *is* 1 *for the planner and* $\frac{1-\beta}{\beta}\frac{\kappa_i}{\gamma+\kappa_i}+1$ *for the governor. There is an interior debt choice if*

$$E_t\left[\frac{R}{\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)}A_{it+1}^{1/(1-\alpha_i)}+(1-\delta_G)}\right]<\Psi<E_t\left[\frac{R+\delta_G-1}{\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)}A_{it+1}^{1/(1-\alpha_i)}}\right].$$

The governor's debt choice is always higher than the planner's.

This proposition shows that the career concern may indeed lead the governor to take on excessive debt, i.e., a debt level higher than the level chosen by the social planner. To further illustrate the governor's debt choice, 1 depicts d_{it} chosen by both the governor and the planner under the following baseline parameter values:

$$\tau=0.2,\alpha=1/3,R=1.1,\delta_G=0.05,\beta=0.9,\gamma=1,\bar{f}=\bar{a}=0.05,\sigma_f=0.4,\sigma_a=0.4,\sigma_\varepsilon=0.2,\kappa_i=1.$$

The left panel depicts d_{it} by varying κ_i between 0 and 10. The governor's debt choice coincides with the planner's choice when $\kappa_i=0$. As the governor's career incentive rises with κ_i, his debt choice also rises with κ_i. The right panel depicts the debt choices of the governor and the planner by varying the expected productivity growth $E\left(A_i\right)$. As expected, both debt choices are increasing with the expected productivity growth rate, with the governor's debt choice always higher than the planner's. Taken together, Proposition 5 describes a mechanism for the rapidly rising leverage in China to be driven by the agency problem between the local and central governments.

5 Innovations and Leverage Spillover

Policy innovations and financial innovations can complicate the agency problem between the central and local governments. In this section, we analyze a novel channel, through which innovations can cause short-termist leverage choice by one governor to spill over to other governors.

Our discussions of local governors' career concerns so far build on the premise that the central government perfectly anticipates the governors' short-termist behaviors (such as over-reporting and over-leverage) with rational expectations and, consequently, is able to perfectly filter out the effect of any short-termist behavior of one governor on the performance evaluation of other governors. This means that short-termist behaviors do not spread across governors. Innovations may prevent the central government from fully anticipating the short-termist behaviors of local governments. First, as part of the key, gradualistic approach adopted by China to reform its economy in the past 40 years, the central government encouraged local officials to experiment with policy reforms and innovations at regional levels, and also encouraged officials to follow and imitate promising policy initiatives of other regions. When a new policy initiative emerges, the central government would often take a passive mode of simply observing its effects before eventually determining whether to endorse or terminate it. Xu (2011) gives an extensive review of this reform approach and argues that it played an important role in China's institutional development. This reform approach implies that the central government is slow by design in catching up with the policy innovations of local governments.

Second, financial innovations further complicate the learn process of the central government in figuring out new strategies or games created by local governments. This is because financial innovations provides new instruments and new arrangements for local government to strategically hide or reveal part of their financial transactions and fiscal situations to the central government. For example, various shadow banking products, such as wealth management products, allow banks to move regular bank loans to local government financing vehicles off their own balance sheets, and, in doing this, also make at least some of these loans off the radar screen of the central government. As we discussed in Section 3, the central government has to rely on local governments to report local economic statistics. While it is easy for the central government to anticipate the incentive for local governments to inflate the aggregate economic output, the lack of reliable statistics make it much more difficult for the central government to figure out complicated financial arrangements and investments made by local governments in different categories.

When the central government does not fully anticipate the debt and investment levels taken by each local government, the tournament between the regional governments may take a somewhat different form because short-termist behavior by one governor can also motivate other governors to take on more short-termist strategies, which in turn may feed back to the initial governor, leading to a rat race among the governors. To formally address this issue, we suppose that the central government gradually updates its anticipation of each local government's investment by setting $G_{it}^{*} = G_{it-1}$, which is similar in nature to adaptive expectations.[3] Following the central government's learning of governor i in (9), we have

$$\begin{aligned} \hat{a}_{it} - \bar{a}_i \;&=\; \lambda \left[\left(f_t - \bar{f} \right) + \left(a_{it} - \bar{a}_i \right) + \varepsilon_{it} + \left(1 - \alpha_i \right) \left(\ln G_{it} - \ln G_{it-1} \right) \right] \\ & \quad -\lambda' \sum_{j \neq i} \left[\left(f_t - \bar{f} \right) + \left(a_{jt} - \bar{a}_j \right) + \varepsilon_{jt} + \left(1 - \alpha_j \right) \left(\ln G_{jt} - \ln G_{jt-1} \right) \right] \end{aligned}$$

where

$$\lambda = \frac{\sigma_a^2 \left(\sigma_a^2 + \sigma_\varepsilon^2 + (M-1)\, \sigma_f^2 \right)}{\left(\sigma_a^2 + \sigma_\varepsilon^2 \right) \left(\sigma_a^2 + \sigma_\varepsilon^2 + M \sigma_f^2 \right)} \text{ and } \lambda' = \frac{\sigma_a^2 \sigma_f^2}{\left(\sigma_a^2 + \sigma_\varepsilon^2 \right) \left(\sigma_a^2 + \sigma_\varepsilon^2 + M \sigma_f^2 \right)}.$$

An immediate consequence of the central government's adaptive expectations is that each local governor's career concern is no longer immune from the investment and leverage choices of other governors, as reflected by the summation term involving G_{jt} in this formula.

In practice, the central government often compares the performance of a governor with another governor in a region with similar economic conditions. Building on the linear career

[3] In fact, the specific form of how G_{it}^{*} is updated is not particularly important. As long as it is delayed and $G_{it}^{*} \neq G_{it}$, the investment and leverage choices of one governor would interfere the evaluation of other governors.

incentive specified in (13), we also add another quadratic term to the governor's career incentive:

$$V(W_{it}) = \max_{G_{it+1},\, D_{it}} E_t\left[\gamma \ln\ (E_{it}^G) + \kappa_i(\hat{a}_{it+1} - \hat{a}_{i't+1}) - \phi_i(\hat{a}_{it+1} - \hat{a}_{i't+1})^2 + \beta V(W_{it+1})\right], \tag{15}$$

where i' is another governor paired with i. The quadratic term gives an increasing incentive for governor i to catch up with the other governor. As there are a large number of other governors, we suppose that i' is chosen to have the same level of infrastructure in the previous period: $G_{i't} = G_{it}$ and $W_{i't} = W_{it}$. This pairing allows us to maintain simplicity of the derivation without any loss of generality. We also make the setting symmetric so that $\bar{a}_i = \bar{a}_j = \bar{a}$ and $\alpha_i = \alpha_j = \alpha$. Then, we have

$$\hat{a}_{it+1} - \hat{a}_{i't+1} = (\lambda + \lambda')\left[a_{it+1} - a_{i't+1} + \varepsilon_{it+1} - \varepsilon_{i't+1} + (1-\alpha)(\ln G_{it+1} - \ln G_{i't+1})\right].$$

Consequently,

$$E_t\left[\kappa_i(\hat{a}_{it+1} - \hat{a}_{i't+1})\right] = \kappa_i(\lambda + \lambda')(1-\alpha)(\ln G_{it+1} - \ln G_{i't+1}),$$

and

$$E_t\left[\phi_i(\hat{a}_{it+1} - \hat{a}_{i't+1})^2\right] = \phi_i(\lambda + \lambda')^2(1-\alpha)^2(\ln G_{it+1} - \ln G_{i't+1})^2 + const.$$

These two terms reveal that governor i's career concern is affected not only by his own infrastructure investment G_{it+1} but also by the investment of his paired governor i'.

We again rescale the governor's two choice variables as

$$g_{it+1} = \frac{G_{it+1}}{W_{it}} \text{ and } d_{it} = \frac{D_{it}}{G_{it+1}}.$$

The following proposition summarizes the equilibrium between the two paired governors' choices.

Proposition 6 *Given the investment choice $g_{i't+1}$ of governor i', the investment choice g_{it+1} of governor i is determined by the unique positive root of the following equation:*

$$\frac{1}{(1-d_{it})\,g_{it+1}} = 1 + \frac{\gamma}{\frac{\beta\gamma}{1-\beta} + \kappa_i(\lambda + \lambda')(1-\alpha) - \phi_i(\lambda + \lambda')^2(1-\alpha)^2(\ln g_{it+1} - \ln g_{i't+1})},$$

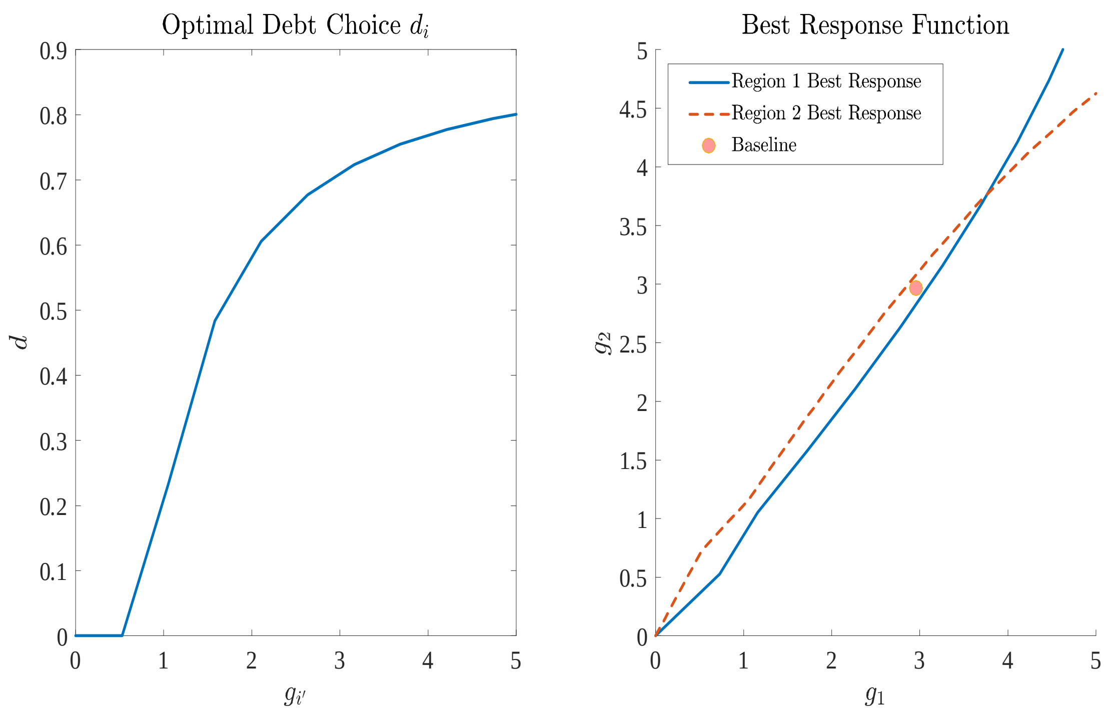

Figure 2: Equilibrium Debt and Investment Choices

which implies g_{it+1} as an increasing function of $g_{i't+1}$ and d_{it}. Governor i's leverage choice d_{it} is given by the following maximization problem:

$$\begin{aligned}\max_{d_{it}}\ & \gamma \ln\left[1-\left(1-d_{it}\right)g_{it+1}\right]+\kappa_i\left(\lambda+\lambda'\right)\left(1-\alpha\right)\left(\ln g_{it+1}-\ln g_{i't+1}\right)\\ & -\phi_i\left(\lambda+\lambda'\right)^2\left(1-\alpha\right)^2\left(\ln g_{it+1}-\ln g_{i't+1}\right)^2\\ & +\frac{\beta\gamma}{1-\beta}\left[\ln g_{it+1}+E_t\left[\ln\left(\tau\left(\frac{\alpha_i}{R}\right)^{\frac{\alpha_i}{1-\alpha_i}}A_{it+1}^{\frac{1}{1-\alpha_i}}+\left(1-\delta_G\right)-Rd_{it}\right)\right]\right],\end{aligned}$$

which determines $d_{it}=d_i\left(g_{i't+1}\right)$, and thus governor i's investment response to governor i':

$$g_{it+1}=g_i\left(g_{i't+1}\right). \tag{16}$$

Similarly, governor i''s investment choice $g_{i't+1}$ is an increasing function of g_{it+1} and $d_{i't}$, and leverage choice is a function $d_{i't}=d_{i'}\left(g_{it+1}\right)$, which in turn determines governor i''s investment response to governor i:

$$g_{i't+1}=g_{i'}(g_{it+1}). \tag{17}$$

Equations (16) and (17) jointly determine the equilibrium choices of the two governors.

Proposition 6 shows that the two governors' investment and debt choices are entangled with each other. To illustrate their interactions, we use a numerical example based on the following parameter values:

$$\tau = 0.2, \alpha = 1/3, R = 1.1, \delta_G = 0.05, \beta = 0.9, \gamma = 1, \bar{f} = \bar{a} = 0.05, \sigma_f = 1, \sigma_a = 1, \sigma_\varepsilon = 0.5.$$

In addition, we choose the following incentive parameters for the two governors, denoted as 1 and 2:

$$\kappa_1 = \kappa_2 = 2, \ \phi_1 = \phi_2 = 40.$$

Figure 2 illustrates the equilibrium. Because of the symmetric parameters chosen for the two governors, they make symmetric investment and debt choices. The left panel depicts each governor's debt choice d_i as a function of the other governor's investment choice $g_{i'}$. When $g_{i'}$ is small, d_i is zero. As $g_{i'}$ rises, governor i chooses a higher leverage d_i to finance greater infrastructure investment in his region. The right panel depicts the two governors' investment choices against each other. The dashed line represents the best investment response g_2 of governor 2 to governor 1's investment g_1, while the solid line represents the best investment response g_1 of governor 1 to governor 2's investment g_2. Both of these investment response functions are increasing. The equlibrium lies at the intersection of these two lines.

To further highlight the interactions between the two governors' investment choices, we increase the incentive parameter κ_2 of governor 2 from the initial value of 2 to 3. Figure 3 illustrates the changes in the equilibrium by plotting the investment response curves of both governors 1 and 2. Point a in the plot is the initial equilibrium with $g_1 = g_2 = 3.77$. As κ_2 rises from 2 to 3, governor 2 becomes more aggressive in his investment and debt choices, and his best response curve shown by the dashed line moves up. If governor 1's investment choice g_1 is kept at the initial value, governor 2's investment choice will move up to point b_1, which is accompanied by a corresponding increase in his debt choice not shown in the figure. However, with g_2 increased, governor 1 would also respond to increase his investment to a level given by point b_2, which in turn stimulates governor 2 to increase his investment level further to b_3, and so on and so forth. This rat race dynamics would eventually converge and drive the equilibrium to point b, which has substantially larger investment increase for governor 2 than his initial increase if governor 1's investment choice stays unchanged. Through this rat

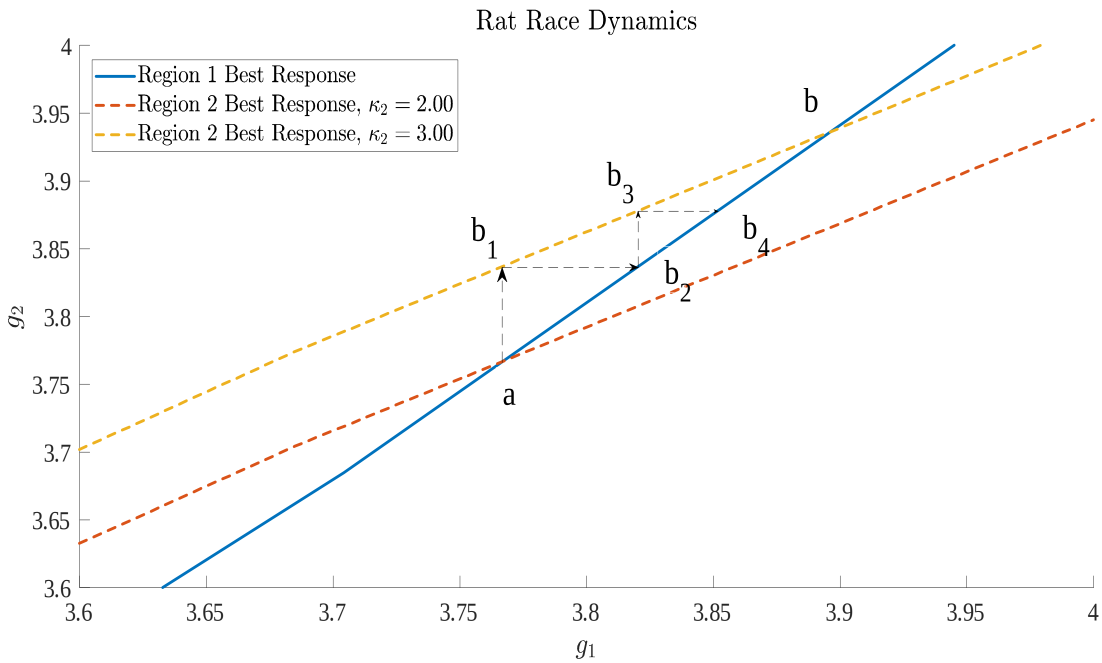

Figure 3: Rat Race Dynamics

race, the change in the career incentive of governor 2 also leads to a substantial increase in the investment choice of governor 1.

6 Conclusion

This paper expands a standard growth model to incorporate the economic tournament between regional governments as a key factor for China's rapid economic growth and the short-termist behaviors induced by the tournament as a mechanism to explain various economic challenges currently confronting China, such as unreliable economic statistics and rising leverage through a booming shadow banking sector.

A Appendix

A.1 Proof for Proposition 1

By substituting in the various consumption components in the Bellman equation (4), we have

$$V\left(W_{it}\right)=\max_{G_{it+1}} \; E_t\left[\gamma \ln\left(W_{it}-G_{it+1}\right)+\beta V\left(\left(1-\delta_G\right)G_{it+1}+\tau Y_{it+1}\right)\right]. \tag{18}$$

We conjecture that

$$V\left(W\right)=k_w \ln W+k_0.$$

Then, the right hand side of Bellman equation (18) is

$$\begin{aligned}
& \max_{G_{it+1}} \; E_t\left[\gamma \ln\left(W_{it}-G_{it+1}\right)+\beta V\left(\left(1-\delta_G\right)G_{it+1}+\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)}G_{it+1}\right)\right] \\
= & \max_{G_{it+1}} \; E_t\left\{\gamma \ln\left(W_{it}-G_{it+1}\right)+\beta k_w\left[\ln G_{it+1}+\ln\left(\left(1-\delta_G\right)+\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)}\right)\right]+\beta k_0\right\} \\
= & \max_{G_{it+1}} \; \gamma \ln\left(W_{it}-G_{it+1}\right)+\beta k_w \ln G_{it+1}+\beta k_w E_t\left\{\ln\left(\left(1-\delta_G\right)+\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)}\right)\right\}+\beta k_0
\end{aligned}$$

Then, the first order condition gives

$$\frac{\beta k_w}{G_{it+1}}=\frac{\gamma}{W_{it}-G_{it+1}},$$

which directly implies that

$$G_{it+1}=\frac{\beta k_w}{\gamma+\beta k_w}W_{it}.$$

The government spending is then $\frac{\gamma}{\gamma+\beta k_w}W_{it}$.

Then, the right hand side of the Bellman equation becomes

$$\begin{aligned}
& \gamma \ln\left(W_{it}-G_{it+1}\right)+\beta k_w \ln\left(G_{it+1}\right)+\beta k_w E_t\left\{\ln\left(\left(1-\delta_G\right)+\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)}\right)\right\}+\beta k_0 \\
= & \left(\gamma+\beta k_w\right)\ln\left(W_{it}\right)+\ln\left(\frac{\gamma}{\gamma+\beta k_w}\right)+\beta k_w \ln\left(\frac{\beta k_w}{\gamma+\beta k_w}\right) \\
& +\beta k_w E_t\left\{\ln\left(\left(1-\delta_G\right)+\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)}\right)\right\}+\beta k_0
\end{aligned}$$

To equate this with the left hand side, $k_w \ln W_i+k_0$, we need

$$k_w=\gamma+\beta k_w, \;\; \Rightarrow \;\; k_w=\frac{\gamma}{1-\beta}$$

and that

$$\begin{aligned}
k_0 \;=\; & \ln\left(\frac{\gamma}{\gamma+\beta k_w}\right)+\beta k_w \ln\left(\frac{\beta k_w}{\gamma+\beta k_w}\right) \\
& +\beta k_w E_t\left\{\ln\left(\left(1-\delta_G\right)+\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)}\right)\right\}+\beta k_0,
\end{aligned}$$

which gives that

$$k_0 = \frac{1}{1-\beta}\left[\ln\left(\frac{\gamma}{\gamma+\beta k_w}\right)+\beta k_w \ln\left(\frac{\beta k_w}{\gamma+\beta k_w}\right)\right] + \frac{\beta}{(1-\beta)^2}E_t\left\{\ln\left((1-\delta_G)+\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)}A_{it+1}^{1/(1-\alpha_i)}\right)\right\}.$$

Thus, $G_{it+1} = \beta W_{it}$.

A.2 Proof of Proposition 2

We have the following Bellman equation for the planner:

$$V\left(W_{it}^{planner}\right) = \max_{G_{it+1},C_{it}^{t},C_{it}^{t-1},E_{it}^{G}} E_t\left[\ln\left(C_{it}^{t}\right)+\ln(C_{it}^{t-1})+\gamma\ln E_{it}^{G}+\beta V\left(W_{it+1}^{planner}\right)\right]$$

subject to

$$C_{it}^{t}+C_{it}^{t-1}+E_{it}^{G}+G_{it+1} = W_{it}^{planner}.$$

We again conjecture that

$$V(W) = k_w \ln W + k_0$$

then,

$$\begin{aligned}
& V\left(W_{it}^{planner}\right) \\
= & \max_{G_{it+1},C_{it}^{t},C_{it}^{t-1},E_{it}^{G}} E_t\left[\ln\left(C_{it}^{t}\right)+\ln(C_{it}^{t-1})+\gamma\ln E_{it}^{G}+\beta k_w\ln\left(W_{it+1}^{planner}\right)+\beta k_0\right] \\
= & \max_{G_{it+1},C_{it}^{t},C_{it}^{t-1},E_{it}^{G}} E_t\left[\ln\left(C_{it}^{t}\right)+\ln(C_{it}^{t-1})+\gamma\ln E_{it}^{G}+\beta k_w\ln\left(Y_{it+1}+(1-\delta_G)G_{it+1}\right)+\beta k_0\right] \\
= & \max_{G_{it+1},C_{it}^{t},C_{it}^{t-1},E_{it}^{G}} E_t\left[\begin{array}{c}\ln\left(C_{it}^{t}\right)+\ln(C_{it}^{t-1})+\gamma\ln E_{it}^{G}+\beta k_w\ln\left(G_{it+1}\right) \\ +\beta k_w\ln\left(\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)}A_{it+1}^{1/(1-\alpha_i)}+(1-\delta_G)\right)+\beta k_0\end{array}\right]
\end{aligned}$$

The first order conditions with respect to $G_{it+1}, C_{it}^{t}, C_{it}^{t-1}, E_{it}^{G}$ give

$$\frac{1}{C_{it}^{t}} = \frac{1}{C_{it}^{t-1}} = \frac{\gamma}{E_{it}^{G}} = \frac{\beta k_w}{G_{it+1}}.$$

The budget constraint then implies that

$$\begin{aligned}
C_{it}^{t} &= C_{it}^{t-1} = \frac{1}{2+\gamma+\beta k_w}W_{it}^{planner} \\
E_{it}^{G} &= \frac{\gamma}{2+\gamma+\beta k_w}W_{it}^{planner} \\
G_{it+1} &= \frac{\beta k_w}{2+\gamma+\beta k_w}W_{it}^{planner}
\end{aligned}$$

Furthermore, by equating the coefficients of $\ln W_{it}^{planner}$ on both sides of the Bellman equation, we have

$$k_w = 2 + \gamma + \beta k_w \Rightarrow k_w = \frac{2+\gamma}{1-\beta}.$$

Thus, $G_{it+1} = \beta W_{it}^{planner}$. The infrastructure level is determined by β fraction of the social wealth, rather than the budget of the local government. This is because the social planner also internalizes the welfare of the households, in addition to that of the government.

A.3 Proof of Proposition 3

We need to solve the following Bellman equation:

$$\begin{aligned} V(W_{it}) &= \max_{G_{it+1}} \gamma \ln (W_{it} - G_{it+1}) + \kappa_i \ln G_{it+1} \\ &\quad + \beta E_t \left[V\left(\left((1-\delta_G) + \tau \left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} \right) G_{it+1} \right) \right] \end{aligned}$$

We again conjecture that

$$V(W) = k_w \ln W + k_0.$$

Then, the governor's objective on the right-hand side becomes

$$\begin{aligned} &\max_{G_{it+1}} \gamma \ln (W_{it} - G_{it+1}) + \kappa_i \ln G_{it+1} + \beta k_w \ln (G_{it+1}) \\ &\quad + E_t \left[\beta k_w \ln \left[(1-\delta_G) + \tau \left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} \right] \right] + \beta k_0 \end{aligned}$$

The first order condition for G_{it+1} gives

$$G_{it+1} = \frac{\beta k_w + \kappa_i}{\gamma + \beta k_w + \kappa_i} W_{it}.$$

Equating the two sides of the Bellman equation leads to

$$k_w = \gamma + \kappa_i + \beta k_w, \quad \Rightarrow \quad k_w = \frac{\gamma + \kappa_i}{1-\beta}.$$

Thus,

$$G_{it+1} = \left[\frac{\kappa_i}{\gamma + \kappa_i} (1-\beta) + \beta \right] W_{it}.$$

A.4 Proof of Proposition 4

We now derive the Bellman equation:

$$
\begin{aligned}
V\left(G_{it},T_{it}\right) \;=\; & \max_{G_{it+1},\,\varphi_{it+1}} \gamma\ln\left(\left(1-\delta_G\right)G_{it}+T_{it}-G_{it+1}\right)+\kappa_i\ln\left(G_{it+1}\right)+\kappa_i\left(\varphi_{it+1}-\varphi^*_{it+1}\right) \\
& +\beta E_t\left[V\left(G_{it+1},\tau Y_{it+1}\left(1-\frac{\tau_c}{\tau}e^{\varphi_{it+1}}\right)\right)\right]
\end{aligned}
$$

We conjecture that

$$
V\left(G,T\right)=k_g\ln\left(G\right)+v\left(T/G\right).
$$

The first order condition for G_{it+1} gives that

$$
\frac{\kappa_i+\beta k_g}{G_{it+1}}=\frac{\gamma}{\left(1-\delta_G\right)G_{it}+T_{it}-G_{it+1}},
$$

which directly implies that

$$
G_{it+1}=\frac{\kappa_i+\beta k_g}{\kappa_i+\beta k_g+\gamma}\left[T_{it}+\left(1-\delta_G\right)G_{it}\right].
$$

The first order condition for φ_{it+1} gives that

$$
\kappa_i=\beta\tau_c e^{\varphi_{it+1}}E_t\left[\frac{Y_{it+1}}{G_{it+1}}v'\left(\frac{T_{it+1}}{G_{it+1}}\right)\right],
$$

which further implies that

$$
\varphi_{it+1}=\ln\left[\frac{\kappa_i}{\beta\tau_c E_t\left[\frac{Y_{it+1}}{G_{it+1}}v'\left(\frac{T_{it+1}}{G_{it+1}}\right)\right]}\right].
$$

By substituting G_{it+1} back to the Bellman equation, we have

$$
\begin{aligned}
& k_g\ln\left(G_{it}\right)+v\left(T_{it}/G_{it}\right) \\
= \;& \left(\kappa_i+\beta k_g\right)\ln\left(G_{it+1}\right)+\gamma\ln\left(\left(1-\delta_G\right)G_{it}+T_{it}\right)+\gamma\ln\left(\frac{\gamma}{\kappa_i+\beta k_g+\gamma}\right) \\
& +\kappa_i\left(\varphi_{it+1}-\varphi^*_{it+1}\right)+\beta E_t\left[v\left(\tau\left(1-\frac{\tau_c}{\tau}e^{\varphi_{it+1}}\right)\frac{Y_{it+1}}{G_{it+1}}\right)\right] \\
= \;& \left(\kappa_i+\beta k_g+\gamma\right)\ln\left(G_{it}\right)+\left(\kappa_i+\beta k_g+\gamma\right)\ln\left(1-\delta_G+T_{it}/G_{it}\right) \\
& +\left(\kappa_i+\beta k_g+\gamma\right)\ln\left(\frac{\gamma}{\kappa_i+\beta k_g+\gamma}\right) \\
& -\kappa_i\varphi^*_{it+1}+\beta E_t\left[v\left(\tau\left(1-\frac{\tau_c}{\tau}e^{\varphi_{it+1}}\right)\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)}A_{it+1}^{1/(1-\alpha_i)}\right)\right]
\end{aligned}
$$

Thus,

$$
k_g=\kappa_i+\beta k_g+\gamma \quad\Rightarrow\quad k_g=\frac{\kappa_i+\gamma}{1-\beta}
$$

and

$$v\left(T_{it}/G_{it}\right)=\frac{\kappa_i+\gamma}{1-\beta}\ln\left(1-\delta_G+T_{it}/G_{it}\right)+k_0$$

with

$$\begin{aligned} k_0 &= \beta E_t\left[v\left(\tau\left(1-\frac{\tau_c}{\tau}e^{\varphi_{it}}\right)\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)}A_{it+1}^{1/(1-\alpha_i)}\right)\right] \\ &\quad +\left(\kappa_i+\beta k_g+\gamma\right)\ln\left(\frac{\gamma}{\kappa_i+\beta k_g+\gamma}\right)-\kappa_i\varphi_{it+1}^{*}. \end{aligned}$$

By substituting v into φ_{it+1}, we obtain that

$$\begin{aligned} \varphi_{it+1} &= \ln\left[\frac{\kappa_i}{\beta\tau_c E_t\left[\frac{Y_{it+1}}{G_{it+1}}v'\left(\frac{T_{it+1}}{G_{it+1}}\right)\right]}\right] \\ &= \ln\left[\frac{(1-\beta)\kappa_i}{\beta\tau_c\left(\kappa_i+\gamma\right)E_t\left[\frac{\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)}A_{it+1}^{1/(1-\alpha_i)}}{1-\delta_G+\tau\left(1-\frac{\tau_c}{\tau}e^{\varphi_{it+1}}\right)\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)}A_{it+1}^{1/(1-\alpha_i)}}\right]}\right] \\ &= \ln\frac{(1-\beta)\kappa_i}{\beta\tau_c\left(\kappa_i+\gamma\right)}-\ln\left\{\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)}E_t\left[\frac{A_{it+1}^{1/(1-\alpha_i)}}{1-\delta_G+\tau\left(1-\frac{\tau_c}{\tau}e^{\varphi_{it+1}}\right)\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)}A_{it+1}^{1/(1-\alpha_i)}}\right]\right\} \quad (19) \end{aligned}$$

This equation has a unique root in the interval $(0,\ln\tau-\ln\tau_c)$ under the following inequality conditions:

$$\ln\frac{(1-\beta)\kappa_i}{\beta\tau_c\left(\kappa_i+\gamma\right)}-\ln\left\{\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)}E_t\left[\frac{A_{it+1}^{1/(1-\alpha_i)}}{1-\delta_G+\left(\tau-\tau_c\right)\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)}A_{it+1}^{1/(1-\alpha_i)}}\right]\right\}>0 \quad (20)$$

and

$$\ln\frac{(1-\beta)\kappa_i}{\beta\tau_c\left(\kappa_i+\gamma\right)}-\ln\left\{\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)}E_t\left[\frac{A_{it+1}^{1/(1-\alpha_i)}}{1-\delta_G}\right]\right\}<0. \quad (21)$$

Note that the right-hand side of equation (19) is increasing with κ_i and decreasing with τ_c. The Implicit Function Theorem thus implies that φ_{it+1} is increasing with κ_i and decreasing with τ_c.

A.5 Proof of Proposition 5

We first solve the governor's Bellman equation in (13) by conjecturing that

$$V\left(W_{it}\right)=k_w\ln W+k_0$$

and denoting $d_{it} = \frac{D_{it}}{G_{it+1}}$. Then, the Bellman equation becomes

$$\begin{aligned} & k_w \ln W_{it} + k_0 \\ = & \max_{G_{it+1},\, d_{it}} \gamma \ln \left(W_{it} - (1-d_{it}) G_{it+1}\right) + \kappa_i \left(\ln G_{it+1} - \ln G^*_{it+1}\right) \\ & + \beta k_w E_t \left[\ln \left(\tau Y_{it+1} + (1-\delta_G) G_{it+1} - R d_{it} G_{it+1}\right)\right] + \beta k_0 \\ = & \max_{G_{it+1},\, d_{it}} \gamma \ln \left(W_{it} - (1-d_{it}) G_{it+1}\right) + (\kappa_i + \beta k_w) \ln G_{it+1} - \kappa_i \ln G^*_{it+1} \\ & + E_t \left[\beta k_w \ln \left[(1-\delta_G) + \tau \left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} - R d_{it}\right]\right] + \beta k_0 \end{aligned}$$

The first order condition for G_{it+1} gives that

$$\frac{\beta k_w + \kappa_i}{G_{it+1}} = \frac{\gamma (1-d_{it})}{W_{it} - (1-d_{it}) G_{it+1}}.$$

This condition implies that

$$G_{it+1} = \frac{\beta k_w + \kappa_i}{\gamma + \beta k_w + \kappa_i} \frac{W_{it}}{(1-d_{it})}. \tag{22}$$

Then, the Bellman equation becomes

$$\begin{aligned} & k_w \ln W_{it} + k_0 \\ = & \max_{d_{it}} (\gamma + \kappa_i + \beta k_w) \ln W_{it} + (\kappa_i + \beta k_w) \ln \left(\frac{1}{1-d_{it}}\right) \\ & + \gamma \ln \left(\frac{\gamma}{\gamma + \beta k_w + \kappa_i}\right) + (\kappa_i + \beta k_w) \ln \left(\frac{\beta k_w + \kappa_i}{\gamma + \beta k_w + \kappa_i}\right) - \kappa_i \ln G^*_{it+1} \\ & + E_t \left[\beta k_w \ln \left[(1-\delta_G) + \tau \left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} - R d_{it}\right]\right] + \beta k_0 \end{aligned}$$

Equating the coefficients of $\ln W_{it}$ gives

$$k_w = \gamma + \kappa_i + \beta k_w \Rightarrow k_w = \frac{\gamma + \kappa_i}{1-\beta}.$$

The relevant terms for choosing d_{it} are

$$\begin{aligned} & \max_{d_{it}} (\kappa_i + \beta k_w) \ln \left(\frac{1}{1-d_{it}}\right) + E_t \left[\beta k_w \ln \left[\tau \left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} + (1-\delta_G) - R d_{it}\right]\right] \\ = & \max_{d_{it}} \left(\kappa_i + \frac{\beta(\gamma+\kappa_i)}{1-\beta}\right) \ln \left(\frac{1}{1-d_{it}}\right) \\ & \qquad + \frac{\beta(\gamma+\kappa_i)}{1-\beta} E_t \left[\ln \left[\tau \left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} + (1-\delta_G) - R d_{it}\right]\right] \\ \propto & \max_{d_{it}} \left(\frac{1-\beta}{\beta} \frac{\kappa_i}{\gamma+\kappa_i} + 1\right) \ln \left(\frac{1}{1-d_{it}}\right) + E_t \left[\ln \left[\tau \left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} + (1-\delta_G) - R d_{it}\right]\right] \end{aligned} \tag{23}$$

We now analyze the debt choice of the social planner. We also conjecture that

$$V\left(W_{it}^{planner}\right) = k_w \ln\left(W_{it}^{planner}\right) + k_0.$$

Then, the planner's Bellman equation in (14) becomes

$$\begin{aligned}
& V\left(W_{it}^{planner}\right) \\
= & \max_{G_{it+1}, C_{it}^t, C_{it}^{t-1}, E_{it}^G, D_{it}} \quad E_t\left[\ln\left(C_{it}^t\right) + \ln(C_{it}^{t-1}) + \gamma \ln E_{it}^G + \beta k_w \ln\left(W_{it+1}^{planner}\right) + \beta k_0\right] \\
= & \max_{G_{it+1}, C_{it}^t, C_{it}^{t-1}, E_{it}^G, D_{it}} \quad E_t[\ln\left(C_{it}^t\right) + \ln(C_{it}^{t-1}) + \gamma \ln E_{it}^G + \beta k_w \ln\left(G_{it+1}\right) \\
& \qquad + \beta k_w \ln\left(\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} + (1-\delta_G) - R d_{it}\right) + \beta k_0]
\end{aligned}$$

where $d_{it} = \frac{D_{it}}{G_{it+1}}$.

The Langrange for the maximization problem on the right-hand side is

$$\begin{aligned}
& \ln\left(C_{it}^t\right) + \ln(C_{it}^{t-1}) + \gamma \ln E_{it}^G + \beta k_w \ln\left(G_{it+1}\right) \\
& + \beta k_w E_t\left[\ln\left(\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} + (1-\delta_G) - R d_{it}\right)\right] + \beta k_0 \\
& - \lambda\left(C_{it}^t + C_{it}^{t-1} + E_{it}^G + G_{it+1} - W_{it}^{planner} - G_{it+1} d_{it}\right)
\end{aligned}$$

The first order conditions imply

$$\lambda = \frac{1}{C_{it}^t} = \frac{1}{C_{it}^{t-1}} = \frac{\gamma}{E_{it}^G} = \frac{\beta k_w}{G_{it+1}\left(1 - d_{it}\right)}$$

and

$$\beta k_w E_t\left[\frac{R}{\left(\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} + (1-\delta_G) - R d_{it}\right)}\right] = \lambda G_{it+1}.$$

The budget constraint implies

$$\frac{1}{\lambda} + \frac{1}{\lambda} + \frac{\gamma}{\lambda} + \frac{\beta k_w}{\lambda} = W_{it}^{planner} \Rightarrow \lambda = \frac{2 + \gamma + \beta k_w}{W_{it}^{planner}}.$$

Then,

$$G_{it+1}\left(1 - d_{it}\right) = \frac{\beta k_w}{2 + \gamma + \beta k_w} W_{it}^{planner}$$

and

$$\begin{aligned}
C_{it}^t &= C_{it}^{t-1} = \frac{1}{2 + \gamma + \beta k_w} W_{it}^{planner} \\
E_{it}^G &= \frac{\gamma}{2 + \gamma + \beta k_w} W_{it}^{planner}
\end{aligned}$$

Equating the coefficients of $\ln W_{it}$ on both sides of the Bellman equation again gives $k_w = \frac{\gamma+\kappa_i}{1-\beta}$.Thus, the relevant terms in the planner's choice of d_{it} are

$$\begin{aligned} & \ln\left(C_{it}^{t}\right) + \ln(C_{it}^{t-1}) + \gamma \ln E_{it}^{G} + \beta k_w \ln\left(G_{it+1}\right) \\ & +\beta k_w E_t \left[\ln\left(\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} + (1-\delta_G) - Rd_{it}\right)\right] + \beta k_0 \\ \propto \; & \ln\left(\frac{1}{1-d_{it}}\right) + E_t\left[\ln\left(\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} + (1-\delta_G) - Rd_{it}\right)\right] \end{aligned} \tag{24}$$

It is interesting to note that the two terms in (23) for the governor's debt choice are the same as the two terms in (24) for the planner's debt choice, except that the coefficient of the first term for the governor's debt choice is larger than that for the planner's choice. We thus write the objectives of the governor and the planner in the following general form

$$\max_{d_{it}} \; \Psi \ln\left(\frac{1}{1-d_{it}}\right) + E_t\left[\ln\left(\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} + (1-\delta_G) - Rd_{it}\right)\right]$$

where the coefficient of the first term Ψ is 1 for the planner and $\frac{1-\beta}{\beta}\frac{\kappa_i}{\gamma+\kappa_i}+1$ for the governor.

The first order condition of the debt choice is

$$\underbrace{\Psi\frac{1}{1-d_{it}}}_{f_1(d_{it})} - \underbrace{E_t\left[\frac{R}{\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} + (1-\delta_G) - Rd_{it}}\right]}_{f_2(d_{it})} = 0.$$

Due to the logarithmic utility for all agents in the model, neither the governor nor the planner would engage in any possibility of default. Thus, they would both choose debt $d_{it} \in \left[0, \frac{1-\delta_G}{R}\right]$ so that their budget would never turn negative. Note that both $f_1(d)$ and $f_2(d)$ are positive and increasing. The following conditions ensure an interior solution to this first order condition:

$$f_1(0) > f_2(0) \text{ and } f_1\left(\frac{1-\delta_G}{R}\right) < f_2\left(\frac{1-\delta_G}{R}\right),$$

which are equivalent to

$$\Psi > E_t\left[\frac{R}{\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)} + (1-\delta_G)}\right] \text{ and } \Psi < E_t\left[\frac{R+\delta_G-1}{\tau\left(\frac{\alpha_i}{R}\right)^{\alpha_i/(1-\alpha_i)} A_{it+1}^{1/(1-\alpha_i)}}\right].$$

As the coefficient Ψ is larger for the governor's decision, the governor's debt choice is higher in order to satisfy the first-order condition.

A.6 Proof of Proposition 6

To solve the Bellman equation specified in (15), we again assume $V(W_{it}) = k_w \ln(W_{it}) + k_0$, as suggested by the derivation in the previous section. Then, by substituting in $E_{it}^G = W_{it} + D_{it} - G_{it+1}$ and rescaling the choice variables as

$$g_{it+1} = \frac{G_{it+1}}{W_{it}} \text{ and } d_{it} = \frac{D_{it}}{G_{it+1}},$$

we have

$$\begin{aligned}\max_{g_{it+1},\, d_{it}} \quad & \gamma \ln W_{it} + \gamma \ln\left[1-(1-d_{it})\, g_{it+1}\right] + \kappa_i (\lambda+\lambda')(1-\alpha)(\ln g_{it+1} - \ln g_{i't+1}) \\ & -\phi_i (\lambda+\lambda')^2 (1-\alpha)^2 (\ln g_{it+1} - \ln g_{i't+1})^2 \\ & + \beta k_w \left[\ln W_{it} + \ln g_{it+1} + E_t\left[\ln\left(\tau\left(\frac{\alpha_i}{R}\right)^{\frac{\alpha_i}{1-\alpha_i}} A_{it+1}^{\frac{1}{1-\alpha_i}} + (1-\delta_G) - R d_{it}\right)\right]\right] + \beta k_0\end{aligned}$$

The first order condition for g_{it+1} gives

$$\frac{\gamma(1-d_{it})}{1-(1-d_{it})\, g_{it+1}} = \left[\beta k_w + \kappa_i(\lambda+\lambda')(1-\alpha) - \phi_i(\lambda+\lambda')^2(1-\alpha)^2(\ln g_{it+1} - \ln g_{i't+1})\right]\frac{1}{g_{it+1}}$$

which in turn gives

$$\frac{1}{(1-d_{it})\, g_{it+1}} = 1 + \frac{\gamma}{\beta k_w + \kappa_i(\lambda+\lambda')(1-\alpha) - \phi_i(\lambda+\lambda')^2(1-\alpha)^2(\ln g_{it+1} - \ln g_{i't+1})} \tag{25}$$

which has a unique root for g_{it+1} in $(0,\infty)$, for a given d_{it}. This root is increasing with both $g_{i't+1}$ and d_{it}.

Equating the coefficients of $\ln W_{it}$ on both sides gives

$$k_w = \gamma + \beta k_w \Rightarrow k_w = \frac{\gamma}{1-\beta}$$

Then, the leverage choice is determined by

$$\begin{aligned}\max_{d_{it}} \; & \gamma \ln\left[1-(1-d_{it})\, g_{it+1}\right] + \kappa_i(\lambda+\lambda')(1-\alpha)(\ln g_{it+1} - \ln g_{i't+1}) \\ & -\phi_i(\lambda+\lambda')^2(1-\alpha)^2(\ln g_{it+1} - \ln g_{i't+1})^2 \\ & +\beta k_w\left[\ln g_{it+1} + E_t\left[\ln\left(\tau\left(\frac{\alpha_i}{R}\right)^{\frac{\alpha_i}{1-\alpha_i}} A_{it+1}^{\frac{1}{1-\alpha_i}} + (1-\delta_G) - R d_{it}\right)\right]\right]\end{aligned}$$

where $g_{it+1}(d_{it}; g_{i't+1})$ is given by (25). This optimization problem leads to an optimal choice

$$d_{it} = d_{it}(g_{i't+1}).$$

Symmetrically, we have

$$d_{i't} = d_{i't}\left(g_{it+1}\right).$$

These two equations jointly determine the two governors' debt choices and lead to rat-race dynamics.

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