Information Asymmetry, Fiscal Competition and Optimal Interregional Transfer

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Abstract

This paper explores the optimal intergovernmental transfer policy when there exists information asymmetry between one central government and multiple local governments. The central government allocates transfers based on observable local output, which is influenced by local private information, output shocks, and endogenous fiscal expenditures. Local governments also leverage their private information to engage in interregional fiscal competition. Theoretically, the optimal transfer policy functions simultaneously as interregional insurance, information rent, and Pigouvian taxation correcting fiscal competition. The information rent is further decomposed into behavioral elasticities and multipliers capturing how the deviation from the IC constraint influences social welfare. Using 2019 Chinese county-level fiscal data, we find that the optimal transfer payment exhibits an inverted U-shape with per capita GDP, emphasizing its roles in providing inter-regional insurance and incentivizing local expenditure efforts. Specifically, we quantify the effects of information asymmetry, local governors' competitive motivations, and economic fluctuations on the optimal transfer policy.

Keywords: interregional transfer; information asymmetry; fiscal competition

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These authors contributed equally to this work and share first authorship.

1 Introduction

Information asymmetry between central and sub-national governments has long been a cornerstone of studies on fiscal decentralization. The seminal works of Tiebout (1956) and Oates (1972) favored a decentralized fiscal systems because local governments are presumed to possess superior knowledge than the central government about local characteristics, such as the preferences of regional residents on public goods provision. The information limitation induces the central government to provide a uniform level of public goods across regions. Recent studies argue that local private information is partially observable, since central governments can infer it through observable indicators (Berriel, Gonzalez-Aguado, Kehoe, & Pastorino, 2024; Gaubert, Kline, & Yagan, 2021; Song & Xiong, 2023), which rationalizes the implementation of place-based fiscal policies by the central government. However, as these studies adopt entirely different frameworks, they fail to provide a unified theory to answer how the partial observability determines the optimal design of place-based policies[1].

This article develops a unified framework to investigate the role of observable indicators – determined by both localities' private information and various important factors – in affecting optimal design of place-based central fiscal policy. We discuss a partially decentralized fiscal system with interregional competition, where infinite local governments are heterogeneous in governance abilities unobservable to the central government. Local governments allocate local fiscal revenues to both local productive public goods and non-productive public goods[2]. The central government intervenes in local public goods provision through place-based intergovernmental transfer policies, relying on the observable local final output. We set the output is jointly influenced by local governance abilities, idiosyncratic output shocks, and productive public investments, all of which are factors separately discussed by previous literature. Besides, due to unobservable local governance abilities, local governors have incentives to "window-dress" their fiscal performance by achieving higher GDP through public investment. Therefore, the interregional tournament arises, as illustrated in Song and Xiong (2023)[3].

In our model, local output is a misleading indicator of local heterogeneities for the transfer policy due to two key issues: disturbances that confound output signals and endogenous incentives for local governments to manipulate output levels. Moreover, local governments' incentives are multidimensional: (1) mitigating residents' risk exposure to local economic shocks through ex-ante public investment as a form of imperfect self-insurance; (2) participating in interregional expenditure competition, which encourages them to inflate output levels and generates externality problem

[1] Separately, previous literature investigates factors affecting the observability including exogenous factors, such as disturbance terms such as aggregate shocks discussed in the literature on monetary unions (Dmitriev & Hoddenbagh, 2019; Evers, 2012; Farhi & Werning, 2017) or noise in signals (Berriel et al., 2024), and the endogenous fiscal behavior of local governments such as public expenditures (Boadway, Horiba, & Jha, 1999; Lockwood, 1999; Song & Xiong, 2023).

[2] This is a partially decentralized fiscal system because in this economy, local governments make their own spending decisions based on local tax revenues income, while the central government also reallocates fiscal resources funded by the central tax revenues.

[3] As local governments have autonomy in making fiscal decisions, literature emphasizes the existence of fiscal competition among regions under such decentralized systems (Bellofatto & Besfamille, 2018; Janeba & Wilson, 2011). Here we focus on expenditure competition among regions because local expenditures play a critical and direct role in determining observable local output.

across regions (Bordignon, Cerniglia, & Revelli, 2003; Foucault, Madies, & Paty, 2008; Revelli, 2005); and (3) concealing both their private information (governance abilities) and their efforts (public investments), thereby generating adverse selection and moral hazard challenges. To address these issues above, we analyze optimal intergovernmental transfer in a Mirrleesian principal-agent framework but extended by: (1) introducing moral hazard into the canonical adverse selection model, as discussed in Boadway and Sato (2015); Castro-Pires, Chade, and Swinkels (2024); Kapička and Neira (2019); (2) considering the externalities induced by interregional competition, and (3) incorporating fiscal decentralization into this framework.

The theoretical analysis reveals that the optimal marginal transfer is determined by the information rent resulting from moral hazard and adverse selection, risk attitude and self-insurance motivation of local governments, the central government's targets, and other parameters related to the fiscal decentralization system. We further decompose the information rent using sufficient statistics into the behavioral elasticity term and welfare multiplier terms related to risks, trade-off of local public goods and externalities. The former reveals how factors including private information, output shocks, and interregional competition affect the optimal transfer by distorting local governments' fiscal choices, leading them to deviate from truth-telling behavior. The latter ones reflect the direct welfare effects of increasing fiscal expending induced by these factors.

Next we numerically simulate optimal transfer based on county-level data from China. The optimal transfer follows an inverse U-shaped pattern. The ascending section of the transfer curve is designed to provide less developed regions with an incentive for public investment expansion, while the descending section highlights the transfers' three roles in risk sharing, promoting interregional equity, and as a Pigouvian tax to correct externalities. Compared to the current transfer policies in China, our optimal design advocates for increasing subsidies to regions with low to medium GDP per capita by reallocating fiscal funds from regions with higher GDP per capita. This approach effectively reduces disparities in per capita public services and mitigates local exposure to macroeconomic risks.

Based on the theoretical and numerical analysis, this article elucidates the impacts of following three factors in shaping the optimal place-based fiscal policy. The first is the local private information. In the absence of asymmetric information (the first best), the central government can perfectly disentangle disturbances from local output levels, enabling transfer policies to provide interregional full insurance in the first-best scenario. Conversely, as shown in our numerical simulations, the presence of information asymmetry can reverse the sign of optimal marginal transfers from negative to positive, in order to prevent low-output regions from reducing their expenditure efforts. This suggests that a completely redistributive transfer schedule, which decreases with per capita GDP– especially in low-output regions– is inefficient, as it can hardly settle the information friction problem in fiscal decentralization.

Second, local output shocks impact the dual roles of transfers: providing interregional insurance and addressing moral hazard through information rents. On the one hand, the larger uncertainty weakens local governments' ability to manage the risks via public investment, which necessitates a more redistributive marginal transfer curve, highlighting the role of transfers as interregional insurance. On the other hand, when faced with a higher standard error of local economic shocks, local governments have stronger incentives to increase investment spending to enhance their self-insurance capacities. This, however, may lead to even greater exposure to the risks of insufficient provision of non-productive public goods, especially in low-output regions. Consequently, the information rent for low-ability regions need to be reduced to prevent aggressive investment spending and volatile output. Overall, we see an increase in transfers to low-output regions but a decline in transfers to medium- and high-output regions. Additionally, from the decomposition of the information rent, we further reveal that output shocks not only incentivize local governments to deviate from incentive-compatible fiscal behavior, as indicated by behavioral elasticities, but also affect the extent to which this behavioral change impacts social welfare and, consequently, the optimal level of information rent.

At last, local governors' career concerns determine the externality effects of fiscal competition. Our theoretical analysis demonstrates that interregional tournaments impact the optimal transfer design by influencing the information rent, necessitating transfers to function as a form of Pigouvian taxation. We calibrate the distribution parameters of governance abilities and the weights that indicate the extent to which local governments care about their careers. Both parameter distributions are being estimated for the first time using county-level data in China. The result reveals that levels of concern are high in the lowest-ability regions and begin to rise in the middle of the ability range, while the highest-ability regions reversely turn to show a corresponding decrease in concern about competition. Moreover, as levels of career concern decline across all regions, the optimal marginal transfer also decreases because the central government prioritizes interregional redistribution over correcting fiscal behavioral distortions in this context. With diminished career concern incentives, as the externality is alleviated, the average amount of transfer increases due to enhanced social efficiency.

This paper makes contributions in three key dimensions: developing a new analytical framework for place-based fiscal policies, separating the effects of uncertainties on agents' incentives, and incorporating the career concern problem within the context of fiscal decentralization.

Our first contribution is applying the Mirrleesian principal-agent model to the transfer design problem, so that we can address the efficiency loss induced by information asymmetry between central and local governments. Unlike a few studies that employed this framework in topics related to fiscal decentralization (Bordignon, Manasse, & Tabellini, 2001; Lockwood, 1999; Persson & Tabellini, 1996), we present a more analytical optimal transfer rule with a clearer decomposition of the roles of various factors in determining the transfer and the information rent. We also numerically demonstrate that optimal transfers in the first-best and second-best cases may exhibit opposite signs in low-output regions.

Second, beyond the literature emphasizing the risk-sharing challenges while neglecting the information structures (Evers, 2012; Farhi & Werning, 2017), we simultaneously discuss the moral hazard and adverse selection issues and separate the incentive impacts of risks on the optimal policy from the insurance effects. The insurance considerations shape the optimal policy through three key elements: local residents' risk-aversion, aligning with the inverse elasticity rule outlined in Chetty and Finkelstein (2012), the self-insurance capabilities of local governments via public spending and the information rent. We then decomposes the information rent into welfare multiplier terms which capture risk-insurance and fiscal pressure considerations, and behavioral elasticities, which represent incentive effects. To our knowledge, this is the first study to decompose information rent in this manner, separating the incentive mechanisms of risks.

The final contribution is that we incorporate interregional tournament into a principal-agent model and numerically verify the importance of considering externalities when designing place-based fiscal policies. While certain studies within the field of fiscal federalism have explored electoral mechanisms (Besley & Case, 1995; Besley & Coate, 2003) and yardstick competition (Bordignon et al., 2003; Foucault et al., 2008; Revelli, 2005), the impact of political promotion or electoral processes on the formulation of optimal transfer designs has not been adequately addressed[4]. We explicitly demonstrate the role of transfers as a form of Pigouvian taxation to correct externalities in the optimal transfer design by decomposing the information rent term. Additionally, we calibrate the distribution of the parameter representing the extent to which local governors cares about interregional competition. We show in simulation that the central government can reduce the size of the total transfer by 2.01% after reducing the degree of carrer concern by 20% from the baseline case.

The remainder of the paper is organized as follows: In section 2 we introduce the setup of the principal-agent model. Section 3 gives the theoretical results of optimal transfer policy and its economic insights. Section 4 conducts the numerical simulation of optimal transfer design. Section 5 concludes.

Related Literature. This paper is closely connected to three branches of literature. First, our work contributes to the studies of optimal interregional place-based fiscal policies. We outline two main branches of literature connected to the place-based policies: fiscal unions (Farhi & Werning, 2017) and fiscal federalism (Berriel et al., 2024; Oates, 1972). The former one emphasizes the influence of uncertainties on fiscal policy design and the latter one focuses on information asymmetry[5]. Besides, some research uses spatial general equilibrium model to explore the effects of externalities induced by mobile households on transfer design: Blouri and Ehrlich (2020); Henkel, Seidel, and Suedekum (2021) give a numerical solution of optimal transfer policies in the EU. Fajgelbaum and Gaubert (2020) discuss the inter-governmental transfers in a general equilibrium model with spatial sorting of heterogeneous workers. Gaubert et al. (2021) develops a two-region model featuring heterogeneous workers sorting among regions, which focuses on worker behavior under place-blind income taxation and place-based lump-sum transfer policies, leading to a simplification of local public

[4] Although Song and Xiong (2023) also introduces the career concern model to study Chinese local governmental competition, he did not to discuss the optimal interregional fiscal policies to mitigate this problem, which is the central to our paper.

[5] Early studies like Boadway et al. (1999); Gaubert et al. (2021); Lockwood (1999); Persson and Tabellini (1996) shed light on the asymmetric information problem when designing transfer policies, they fail to give numerical analysis, or simplify the setup of local governments' behavior.

spending. To conclude, none of these studies develops a unified framework to incorporate both information asymmetry and uncertainties. Our work studies the optimal place-based policies in a general equilibrium model, encompassing information asymmetry, regional macroeconomic shocks, and local governments' multiple dimensions of incentives. Moreover, we numerically solve the optimal place-based policies, offering guidance for policy reform.

Second, this paper enriches the discussion of interregional fiscal competition. In the fiscal federalism literature, fiscal competition mainly refers to the competition in terms of taxes. A number of studies explore the tax competition for mobile firms or residents (Bellofatto & Besfamille, 2018, 2021; Janeba & Todtenhaupt, 2018; Janeba & Wilson, 2011). A few studies emphasize the importance of yardstick competition, as it allows electorates with incomplete information to reevaluate municipal governors based on information externalities.(Bordignon et al., 2003; Ferraresi, 2019). Song and Xiong (2023) establishes a career concern model to characterize the governors' yardstick tournament in China. Cai and Treisman (2005) discuss the expenditure competition for mobile capital in China. However, all of these studies fail to discuss how to design fiscal place-based policies under the context of expenditure competition. Our work sheds light on the roles of interregional yardstick competition via the local expenditure choice in a decentralized fiscal system. We apply the yardstick competition into the environment with incomplete information about local governance when designing place-based fiscal policies. This framework can simultaneously discuss the information asymmetry and interregional competition issues, and can also be easily extended to the scenario of tax competition.

The last branch of related literature is the principal-agent model addressing adverse selection and moral hazard. Early explorations on the optimal contract problem under both adverse selection and moral hazard can be found in Laffont and Tirole (1986) and Gottlieb and Moreira (2014). Castro-Pires et al. (2024) raise a disentangling method to solve the optimal contract under a more general setting. While their contract is based on an agent's performance and ability, our work assumes central transfer only depends on local output, which is consistent with the practice in reality. A setup similar to our work also appears in the context of optimal income taxation. Boadway and Sato (2015) consider the case where consumers' incomes are jointly determined by unobservable abilities and income shocks. Kapička and Neira (2019) also studies the interaction of moral hazard and adverse selection in the setting of human capital investment. This paper differs from previous works by developing a comprehensive framework that incorporates interregional competition, as described in Song and Xiong (2023), along with canonical local heterogeneities and disturbances. Additionally, it is noteworthy that we disentangle the information rent term using sufficient statistics, allowing us to highlight the influence of various factors shaping the optimal policy – an approach not undertaken by prior literature (Boadway & Sato, 2015; Chetty & Finkelstein, 2012; Low & Maldoom, 2004).

2 Model Environment

We build a model featuring information asymmetry between two tiers of government—the central government and regional governments, as discussed in Song and Xiong (2023) – to study the optimal design of interregional transfer policies. Given the tax-sharing rate between the central and local governments, along with the transfer rule announced in advance by the central government, local governments first decide on the amount of productive fiscal expenditures. Subsequently, local governments encounter idiosyncratic output shocks. Once these output shocks are realized, transfers are distributed according to the predetermined rule, while non-productive, utility-enhancing fiscal expenditures are determined ex-post. Besides, there exist interregional tournaments based on the performance of local economies, which will be discussed later in Section 2.3.

In the first-generation theory of fiscal federalism developed by Oates (1972), the core assumption underlying the rationale of fiscal decentralization between central and local governments is that local governments have better knowledge of regional residents' preferences for public goods than the central government. The central government can only provide a uniform level of public goods for each region, and there are no interregional spillover effects of local public goods. Under these assumptions, a decentralized fiscal system where local governments provide public goods according to local conditions is inevitably superior to a centralized fiscal system. However, Berriel et al. (2024) argue that when the central government can update its expectations based on observed signals of local information, it becomes feasible for the central government to design place-based public spending policies, thereby challenging the original assumption.

In this paper, the levels of local economic output serve as the observable signals released by local governments. Due to random output shocks, the central government can only partially infer local productivity by observing output. This introduces a signaling problem between the central and local governments into the context of fiscal decentralization , which also challenges the traditional assumption of fiscal federalism theory. Moreover, unlike in Berriel et al. (2024), where shocks only affect the central government's updating process, in this paper, economic shocks directly impact local output, thereby endowing transfers with a risk-sharing function. Compared to related works only addressing the adverse selection problem (Berriel et al., 2024; Gaubert et al., 2021; Lockwood, 1999), the introduction of uncertainty necessitates a comprehensive theoretical framework simultaneously addressing moral hazard and adverse selection.

Another key difference between this paper and canonical fiscal decentralization theory is the introduction of externalities generated by interregional competition. Externalities of local public goods are excluded by the assumption of the first-generation theory of fiscal federalism. Besley and Coate (2003) challenge this assumption from a perspective of political economics, arguing that the regional public decisions can influence the levels of public expenditures in other regions through the election system, thereby combining the political economics with fiscal decentralization theorem. This paper breaks this assumption by introducing interregional competition: local governments' public expenditures trigger expenditure competition in other regions, resulting in fiscal policy externalities. Consequently, in this context, transfers must also serve as Pigouvian taxes to mitigate the externalities arising from interregional competition.

In the baseline model, we assume the existence of one central government and two types of regional governments to illustrate the optimal transfer rules. The two types of regional governments are denoted by $i \in \{H, L\}$. Each region contains a representative firm hiring labor and a representative labor-supplier. For simplicity, assume that both firms and labor-suppliers are immobile, while there are a mass of mobile capital owners.

2.1 Firms

The output of the representative firm in the region i is determined by the local productivity A_i, capital K_i, labor L_i and local government's investment (productive) spending G_i. The production function is

$$Y_i = A_i K_i^{\alpha} L_i^{1-\alpha} G_i^{g}, \tag{1}$$

where $\alpha \in (0, 1)$ is the output share of capital. $g \in (0, 1)$ is the elasticity of output to local investment spending. When $g = 1-\alpha$, a local government's investment spending is "labor-augmenting", e.g., infrastructure like subways reducing commuting costs and thus improving the efficiency of supplying labor. Song and Xiong (2023) and Barro and Sala-i Martin (2004) used this form when $g = 1 - \alpha$ because given a fixed labor supply in each region, the production is constant return to scale with K_i and G_i. In this way, they could discuss the balance growth path of the economy. The productivity A_i consists of both the regional governor's ability a_i and an idiosyncratic productivity shock ε_i. Both a_i and ε_i are unobservable to the central government. We adopt the following form of A_i:

$$\log A_i = \Lambda(a_i) + \varepsilon_i. \tag{2}$$

Function $\Lambda(a_i)$ is increasing in a_i. Output shock $\varepsilon_i \in \Omega_F$ captures the economic risk in regional development, where Ω_F is a Borel set and $\mathcal{F}$ is the corresponding Borel σ-algebra. The shocks may reflect the fluctuation of the macro economy, the occurance of regional-specific natural disasters, etc. Use $F^E(\varepsilon)$ to denote the cumulative distribution function of output shock building on $\mathcal{F}$. We assume $F^E(\varepsilon)$ is differentiable and its PDF function is denoted as $f^E(\varepsilon)$. For simplicity, assume that the distributions of a and ε are independent to each other. Both the regional governor's ability a and the realization of output shock ε_i are private information to local governor i, while the exogenous distributions of a and ε are common knowledge to all governments.

There are two typical kinds of regional governments with ability a_H and a_L, with $a_H > a_L > 0$. The central government knows the distribution probability π_H and $\pi_L = 1 - \pi_H$ of these two types of ability, but cannot observe the ability level of any governor.

A representative firm hires capital K_i and labor L_i to maximize the following profit:

$$\max_{\{K_i, L_i\}} A_i K_i^{\alpha} L_i^{1-\alpha} G_i^{g} - \Phi_i L_i - R K_i. \tag{3}$$

Assume all local producers can rent capital from the global capital market at an exogenously given gross return rate R. Since we assume labor is immobile, the wage rate between the two regions can differ. We use Φ_i to denote the wage rate in region i. To abstract the effect of labor supply elasticity from the model, following Song and Xiong (2023), without loss of generality, we normalize the labor supply in all regions to one.

By solving the optimization problem of representative firms, we can express the production function as:

$$Y_i = \left(\frac{\alpha}{R}\right)^{\alpha/(1-\alpha)} A_i^{1/(1-\alpha)} G_i^{g/(1-\alpha)} \tag{4}$$

Equation (4) shows the size of investment spending G_i positively correlates with local output. This is consistent with the facts that governmental spending is essential to economic growth and poverty reduction, especially in developing countries. For instance, Binswanger, Khandker, and Rosenzweig (1993) find infrastructure spending promoted long-run output in India. Liu and Hu (2010) further point out transportation infrastructure and information infrastructure have significant spillover effects on China's economic growth.

2.2 Households

Both labor suppliers and capital owners investing in the same region are local consumers, collectively referred to as "local residents" in our paper. As capital owners are mobile across regions, we make the innocuous assumption that each capital suppliers holds one unit of capital, and after she receives the capital gross return R, she will consume at the location.

Hence the total private goods consumption of consumers in the region i is the sum of both after-tax labor income and after-tax capital income. Without loss of generality, assume the labor supply L_i is inelastic.

Local consumers enjoy the consumption of both private and public goods. Denote by C_i the private good consumption of the consumers in the region i. S_i represents non-productive but utility-enhancing fiscal expenditure provided in the region i, as classified by Barro (1990). The private goods consumption satisfies:

$$C_i = \left(1-\tau^l\right) \Phi_i L_i + \left(1-\tau^k\right) R K_i, \tag{5}$$

in which τ^l and τ^k correspond to the linear labor income tax rate and linear capital income tax rate. It is easy to show that under the Cobb-Douglas production function as in (4), C_i is a linear proportion to regional output Y_i.

$$C_i = \left[\left(1-\tau^l\right)(1-\alpha) + \left(1-\tau^k\right)\alpha\right] Y_i \tag{6}$$

Equation (6) indicates a local government has a trade-off over G_i and S_i. Regional investment spending G_i promotes output and indirectly enhances the consumer's welfare, while regional public goods expenditure S_i directly improves the consumer's welfare. Due to constraints of local fiscal budgets, local governments must balance the provision of these two distinct public goods.

2.3 The Local Government: Budget and Career Concern

In this part, we first present the timeline of local and central governments' decision. Next, based on the timeline, we illustrate interregional fiscal competition (or tournaments) based on the career concern model proposed by Holmstrom (1982). Finally, we introduce the optimization problems of local governments.

Figure 1 illustrates the timeline of interregional tournaments in our model. In this one-period model, the local government obtains ability a_i and chooses the amount of productive investment spending G_i at the beginning of the period. Then an output shock ε_i is realized and Y_i is determined at the end of the period. It is notable that the local government chooses G_i before the realization of output shocks. This is consistent with the reality because G_i primarily involves projects with long investment cycles, such as infrastructure construction, which requires time to yield outcomes.

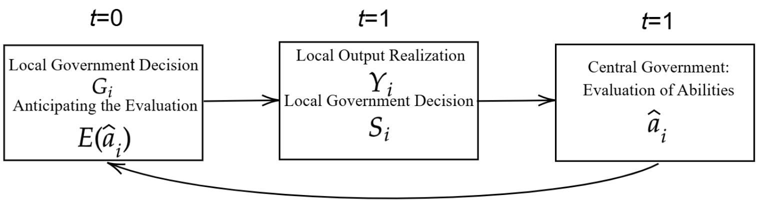

Fig. 1: The timeline of a local government's decisions and central government's evaluation

As soon as the shock is realized, the central government observes the ex-post output of local governments Y_i. The local government collects tax revenues and receives central transfer T_i. Then the amount of public service S_i is determined to ensure a balanced fiscal budget. To capture fiscal decentralization in the model, we denote by ξ^l and ξ^k a local government's retention rate of labor and capital income tax revenue. The fiscal transfer T_i to region i depends on the region's output Y_i. Hence the budget constraint is

$$G_i + S_i = T(Y_i) + \xi^l \tau^l \Phi_i L_i + \xi^k \tau^k R K_i. \tag{7}$$

Based on (4), the above budget constraint can be transformed into:

$$S_i = T(Y_i) + \Omega Y_i - G_i \tag{8}$$

in which $\Omega \equiv \xi^l \tau^l (1-\alpha) + \xi^k \tau^k \alpha$ denotes the share of output retained in local government.

Since the central government cannot observe a_i, it forms the expectation of local government abilities, denoted as $\hat{a}_i$, based on the output level. Define $h(a \mid Y_i)$ as the conditional density function of a local governor's ability when output Y_i is observed , and $\mathbb{G} = \{\mathcal{G} : a \to G(a)\}$ as the collection of functions, where $\mathcal{G} \in \mathbb{G}$. The central government cannot observe abilities or public investment levels G. This assumption can be explained by the fact that, although the central government can monitor total public expenditures within specific regions, the practical isolation of productive investments from diverse expenditure items presents significant challenges. This difficulty arises because expenditure programs aimed at promoting local economies frequently intersect with various budget categories. Local governments may also manipulate or window-dress their fiscal reports, further compounding the challenges of distinguishing productive spending. Nonetheless, policymakers can infer the relationship between abilities and public spending, $\mathcal{G}$, by solving the optimization problem faced by local governments. We can express $\hat{a}_i$ as:

$$\hat{a}_i = \hat{a}(Y_i, \mathcal{G}) = E_a \left[a \mid Y_i, \mathcal{G}\right] = a_H h \left(a_H \mid Y_i\right) + a_L h \left(a_L \mid Y_i\right). \tag{9}$$

$\hat{a}_i$ represents the central government's evaluation of local governance abilities. As discussed in Song and Xiong (2023), the evaluation of local governors' abilities formed by the central government determines the probability of their promotion in the future. Thus the local government, motivated by their political promotion prospects, would care about the expectation of $\hat{a}_i$ before they make expending choice of G. We denote such expectation by $E\left(\hat{a}_i\right)$. Denoting by $F(y \mid a, G(a))$ the conditional distribution function of output given investment spending $G(a)$ and ability type a, we have

$$E\left(\hat{a}_i\right) = \int_{\underline{y}(a_i)}^{\overline{y}(a_i)} \hat{a}_i F_y \left(y \left| a, G\left(a\right)\right.\right) dy. \tag{10}$$

In equation (10), $\overline{y}$ and $\underline{y}$ correspond to the upper and lower bounds of output. Following Boadway and Sato (2015), we assume that both $\overline{y}$ and $\underline{y}$ are functions of a_i, and $\overline{y}$ increases with a_i.

$E\left(\hat{a}_i\right)$ enters local governors' utility functions to capture their concerns of promotion. Additionally, a local government is concerned with the local consumption of both private and public goods. We use function $u(C_i, S_i)$ to capture such welfare concern. Assume that $u_c > 0$, $u_s > 0$, $u_{ss} \leq 0$. Therefore, the ex-ante utility of a local government is

$$U_i = E\left[u\left(C_i, S_i\right)\right] + \chi_i E(\hat{a}_i), \tag{11}$$

where χ_i is the weight assigned to the governor i's career concerns.

A comprehensive understanding of the competitive motivations of local governors can be achieved by integrating equations (9), (11), and (10). Since local governors are concerned with the central government's assessment, the only way to improve the perceived ability level, $\hat{a}$, is by increasing productive public spending. It is notable that $\hat{a}_i$ is determined by the relative position of the output of region i in comparison to the outputs of other regions within the nation, where the expenditure competition arises. There are externalities associated with expenditure competition: an increase in public spending in one region not only enhances the likelihood of promotion in that region but also undermines the utility of other regions by reducing their relative standing in the competition. Given the strategies of the other regions, each region may have the incentive to increase its own productive public spending[6].

A type-i local government's optimization problem is:

$$\max_{\{G_i\}} \quad E\left[u\left(C_i, S_i\right)\right] + \chi_i E(\hat{a}_i)$$
$$\text{s.t.} \quad (4), (6), (8), (9) \quad \text{hold},$$

with the first-order condition on G_i of the optimization problem as:

$$\int_y -u_s(C,S)F_y(y \mid a,G)dy + \int_y u(C,S)F_{yG}(y \mid a,G)dy + \chi \int_y \hat{a}F_{yG}(y \mid a,G)dy = 0. \tag{12}$$

Here we omit script i for simplicity. $F_{yG}(y \mid a,G)$ is the partial derivative of $F_y(y \mid a,G)$ on G. The equation (12) reveals multidimensional incentives of local governments' fiscal choice. If local government i spends more on productive public goods, this action will, on one hand, tighten the budget constraint and directly influence the ex-post provision of non-productive public goods, thereby influencing the marginal cost of increasing G_i. On the other hand, the marginal increase in G_i will alter the distribution of future output and consumption. This generates marginal benefits in two directions. First, it could help hedge against economic uncertainties by thickening the right tail of the distribution of Y_i. Second, a larger investment in production would improve the probability of being promoted in the tournament. The economic uncertainties and tournament mechanism create additional incentives for local governors in the trade-off between various types of public goods spending.

2.4 Central Government

Equation (12) characterizes the expenditure choice of local governments given the transfer schedule announced by the central government at the beginning of the period[7]. Next, we explore the design of optimal transfer rule using the primal approach, where the central government optimizes social welfare by directly allocating resources. The optimal transfer rule should accommodate three main objectives: (1) to promote inter-regional equity as a form of fiscal insurance; (2) to mitigate the efficiency losses caused by fiscal competition; and (3) to address both moral hazard and adverse selection through mechanism design.

Firstly, a benevolent central government designs a fiscal transfer system, funded by tax revenues shared by localities, to maximize the following social welfare W:

$$W = \sum_i \beta_i \left(\int_y u(C_i, S_i)F_y(y \mid a_i, G_i)dy \right) \pi_i \tag{13}$$

[6]However, it cannot be concluded that every region will increase spending compared to a scenario without competition. Local governments must consider the trade-off between providing non-productive services and the productive goods. The fiscal transfer rule will also influence the choice.

[7]We assume that the central government has the full commitment capabilities in order to focus on the mechanisms induced by interregional competition and information asymmetry.

where β_i is the social welfare weight associated with local government i. The welfare weight β_i reflects to what extent the central government emphasizes fiscal equity. Besides, since the welfare function (13) is concave with respect to non-productive public services $\{S_i\}$, the central government is also risk-averse and seeks to provide interregional insurance for local governments via the design of transfers.

Besides, the central government does not encourage the tournaments and therefore the concern about tournaments does not enter into the social welfare function. This setup, analogous to optimal taxation models where agents' utility follows a hyperbolic function, positions the transfer rule as a form of Pigouvian tax aimed at correcting distortions in local fiscal behavior.

The last consideration of the central government is about information asymmetry. To deal with adverse selection and moral hazard issues, the central government offers a menu of contracts that consists of a pair of functions $\{T(y), G(a)\}$[8]. Denote by $V(a_i, G(a_i))$ the utility of a local governor honestly reporting his ability a_i and spending $G(a_i)$, which can be expressed as

$$V(a_i, G(a_i)) = \int_y u\left(C(y), T(y) + \Omega y - G(a_i)\right) F_y(y \mid a, G(a_i))dy + \chi_i \int_y \hat{a}_i F_y(y \mid a, G(a_i))dy, \tag{14}$$

where we substitute S using (8). The central government should ensure incentive compatibility (IC) condition holding as:

$$V(a_i, G(a_i)) \geq V(a_i, G(a_j)), \quad \forall i, j \in \{H, L\} \tag{15}$$

When there are only two types of governors in the benchmark model, the equivalent IC condition equals exactly equation (12)[9]. The local economic uncertainties play important roles in such a principal-agent model. If we remove ε from the model, the IC condition degenerates to a scenario where there is no moral hazard problem. Consequently, the transfer rule only needs to address adverse selection. Besides, although local governments still face the trade-off between two types of public spending, they no longer have the incentive for precautionary saving through increased public investment. As a result, the provision of interregional fiscal insurance against risks is abstracted from the transfer design. Moreover, if there is no uncertainty of local output, the optimal contract condition should ensure that Y_i is monotonically related to a_i. In this case, the central government can accurately infer a region's true relative standing, completely eliminating the room for interregional competition. Therefore, the introduction of ε enriches the economic insights underlying the mechanism design by incorporating risk aversion and competition incentives. We will quantitatively examine the incentives and the associated information rents in Section 3.2.

Central transfers are only a portion of the central government's expenditures, which are funded by tax revenues collected nationwide. The central government also has its

[8]It is notable that the transfer schedule is solely based on output Y. We choose this setup because it aligns with practices observed in many countries.

[9]Condition (15) requires that function $\tilde{V}(a_j) \equiv V(a_i, G(a_i)) - V(a_i, G(a_j))$ has minimum value at $a_j = a_i$. The first-order condition is just the necessary condition of choosing G to maximize $V(a, G)$.

own consumption denoted by Z. As we focus on the expenditure structure of local governments, we assume the central government's consumption Z is a fixed share of fiscal income. We denote by z the ratio of central fiscal income to central government's consumption and also assume Z affects neither residents' utility nor local productivity. Therefore, the central government's budget constraint is

$$Z + \int_y T(y) f^Y(y) dy = \int_y \left(\left(1 - \xi^l\right) \tau^l \Phi(y) + \left(1 - \xi^k\right) \tau^k R K(y) \right) f^Y(y) dy. \tag{16}$$

Equation (16) can be further rewritten as:

$$\sum_i G(a_i)\pi_i + \sum_i \int_y S(y, a_i) F_y(y \mid a_i, G(a_i)) dy \pi_i = \int_y \Gamma y f^Y(y) dy, \tag{17}$$

where we define total retention rate of fiscal revenues at local governments Γ as

$$\Gamma \equiv (1 - \alpha) \left[(1 - z)\left(1 - \xi^l\right) + \xi^l\right] \tau^l + \alpha \left[(1 - z)\left(1 - \xi^k\right) + \xi^k\right] \tau^k. \tag{18}$$

Moreover, the central government also faces the resource constraint:

$$\int_y y f^Y(y) dy = \int_y C(y) f^Y(y) dy + \sum_i \int_y S(y, a_i) F_y(y|a_i, G(a_i)) dy \pi_i + \sum_i G(a_i)\pi_i + Z \tag{19}$$

Therefore, the central government's optimization problem is as follows:

$$\max_{\{G(a_i), C(y), S(y, a_i)\}} \sum_i \beta_i \left(\int_y u\left(C\left(y\right), S\left(y, a_i\right)\right) F_y\left(y | a_i, G\left(a_i\right)\right) dy \right) \pi_i$$

$$\text{s.t.} \quad (12), (17), (19) \quad \text{hold.}$$

Here the central government allocates productive public spending $\{G\}$, private consumption $\{C\}$ and non-productive public spending $\{S\}$. From the budget constraint (8), we can define function $S(y, a_i)$, because the right-hand side of (8) is contingent on both the ex-post output Y and the pre-determined variable $G(a)$.

2.5 Model with Infinite Types of Regions

The optimal transfer policy problem can be readily adapted to a more general scenario involving infinite types of regions. We assume that there is a continuum of infinitesimal sub-national governments, each denoted as $i \in I \subseteq \mathbb{N}_+$. I is a countable set. The heterogeneous governmental abilities are represented by $a \in \Omega_A$, where $\{\Omega_A, \mathcal{A}\}$ forms a Borel space and $\mathcal{A}$ is a Borel sigma-algebra. We define the cumulative distribution function of a based on $\mathcal{A}$ as $F^A(a)$. Assume $F^A(a)$ is differentiable and the corresponding probability density function (PDF) is denoted as $f^A(a)$. The central government's budget constraint under this context is:

$$\int_a G(a)f^A(a)da + \int_a \int_y S(y,a)F_y(y \mid a, G(a))f^A(a)dyda = \int_y \Gamma y f^Y(y)dy, \tag{20}$$

while the resource constraint is:

$$\int_y yf^Y(y)dy = \int_y C(y)f^Y(y)dy + \int_a \int_y S(y,a)F_y(y|a,G(a))f^A(a)dyda + \int_a G(a)f^A(a)da + Z \tag{21}$$

The IC constraint can be rewritten as:

$$V(a_i, G(a_i)) \geq V(a_i, G(a_j)), \quad \forall i,j \in I \tag{22}$$

Then we can find the first-order IC constraint shares the same form with equation (12). The objective function of the central government is to maximize

$$\int_a \beta(a) \int_y u(C(y), S(y,a))F_y(y \mid a, G(a))f^A(a)dyda, \tag{23}$$

subject to the central government's budget constraint (20), the resource constraint (21) and first-order IC constraint (12), which is consistent with the optimization problem of the benchmark model. Notice that the Bayesian updating of the local ability from the central government is now expresses as

$$\hat{a}(y, \mathcal{G}) = E_a[a \mid y, \mathcal{G}] = \int_a ah(a \mid y)da, \tag{24}$$

where $h(a \mid y)$ denotes the conditional probability density function of local governance ability given the output y.

The scenario with infinite types of regions is more practical, but it will not change the economic insights behind our benchmark model. Therefore, we primarily focus on the theoretical analysis of the two-region case, while we simulate optimal transfer under the more practical scenario.

3 Theoretical Results

To better understand the essential insights in designing optimal interregional fiscal policies, we provide the expression of the optimal transfer rule as a function of output but announced before output shocks take place. Through the determinants of the optimal transfer formula and the decomposition of information rent term in the formula, we can evaluate the effects of multiple concerns on optimal transfer design, including fiscal equity, interregional insurance and distortion resulted from information asymmetry and tournaments.

3.1 Optimal Ex-post transfer

Proposition (1) shows the optimal marginal ex-post transfer rule:
Proposition 1. *Define the likelihood ratio $\eta(a, y)$ as:*

$$\eta(a, y) = \frac{F_{yG}(y \mid a, G(a))}{F_y(y \mid a, G(a))} = \frac{\partial \ln F_y(y \mid a, G(a))}{\partial G(a)}. \tag{25}$$

when the utility function $u(C, S)$ is additive with respect to the private consumption C and non-productive public spending S, and the utility function of S takes the form of CARA, the optimal marginal transfer can be expressed as[10]*:*

$$\begin{gathered} T'(y) = \sum_i \tfrac{1}{r_i} \tfrac{\mu_i \eta_y(a_i, y)\pi_i}{\beta_i + \mu_i[\eta(a_i, y) + r_i]} - \Omega, \quad i = H, L; \\ \Omega \equiv \xi^l \tau^l (1 - \alpha) + \xi^k \tau^k \alpha \end{gathered} \tag{26}$$

where μ_i is the co-state variable for the IC constraint. r_i is the risk-aversion coefficient of a local government over public goods. η reflects the elasticity of the PDF of y to the local productive public spending. Referring to Milgrom (1981), we assume $\eta_y > 0$.

See Appendix 6.2.1 for the proof. The equation (26) reflects the key elements determining the design of the optimal marginal transfer: the risk-aversion attitude of local governments, the likelihood ratio, the information rent, the equity preference of the central planner, and the statutory local retention rate determined by the tax-sharing system. The following analysis gives more details of the above four key elements.

Risk-aversion attitude. First, due to the absence of complete insurance tools for local governments against regional economic shocks, the transfer system should serve as an interregional insurance. Hence, the risk-aversion attitudes of local governments determine the distribution of transfers. The following corollary illustrates how risk attitudes influence the extent to which transfers provide security against economic risks:
Corollary 1. *When the utility function with S is in the form of CARA, controlling μ_i and likelihood ratio η_i, an increase of risk-aversion coefficient r_i will lead to the decrease of $T'(y)$*[11]*.*

Corollary 1 suggests that a higher risk-aversion coefficient requires the optimal transfer being less progressive and tilted more towards low-output regions. This observation underscores the risk-sharing function of transfers. The reciprocal of the coefficient of absolute risk aversion, $1/r_i$, corresponds to the insurance effect in the optimal marginal income tax, as discussed in Boadway and Sato (2015). They argue that individuals exhibiting greater risk aversion are subject to higher marginal tax rates. Considering that central transfers can be viewed as the opposite to income taxes, it follows that the marginal transfer will be comparatively lower when faced with greater risk aversion. Consequently, our findings align with the intuition that the

[10] Under the CARA utility, both the coefficient of risk aversion and the coefficient of prudence are equal to the same constant r.

[11] Although in the optimal transfer, it is actually impossible to change r_i while controlling the optimal μ_i and η_i, as Varian (1980) explains, this method can be viewed as a first-order approximation of the marginal change. This corollary reaches a similar conclusion to his work discussing the effect on the marginal tax rate.

relationship between an agent's risk attitude and marginal transfers (or income taxes) remains consistent.

As discussed in the literature, interregional transfers play a crucial role in mitigating regional risks. Asdrubali, Sorensen, and Yosha (1996) show 13% of GDP shocks are smoothed by federal transfers. They also point out that the credit market and capital market smooth 62% of total shocks. However, in developing countries, the incompleteness of capital and credit markets renders fiscal risk-sharing tool even more important. Tochkov (2007) finds that the transfer policy in China offers inadequate insurance for low-income regions. This deficiency highlights the necessity for transfer payment policies to address these gaps.

Likelihood Ratio. The second element is the likelihood ratio η and its derivative η_y. They shapes the central government's efficiency concern and social insurance concern separately. η reflects the difficulty of local governments to change the expected future output via public investment. From definition (25), η can also be interpreted as the elasticity of distribution with respect to local public investment G_i.

In (26), η negatively correlates with $T'(y)$. According to the efficiency principle of optimal social insurance in Baily (1978), the marginal benefit of a smoother output path realized by T' should equates the marginal efficiency cost, measured by the behavioral response in public investment. As marginal efficiency cost is smaller for regions with high η, T' for these regions should be lower, indicating that transfer policy can be more redistributive. The reason why high η corresponds to a low marginal efficiency cost is as follows: a higher value of η implies that $G(a)$ has a greater impact on the probability of achieving output y. When T' increases, local governments are incentivized to increase their investment spending, leading to a larger distortion compared to the case of lump-sum transfers. As a result, T' should not be set too high in order to avoid efficiency losses caused by the overspending of G. Similarly, in the optimal replacement formula in Chetty and Finkelstein (2012), the responsiveness of the distribution of output to unobservable effort appears at the denominator in (26), which coincides with the inverse elasticity rules from the literature on optimal commodity taxation.

η_y represents the marginal change in self-insurance capabilities resulting from a marginal increase in output y. We set $\eta_y > 0$, which is the monotone likelihood ratio property as in Milgrom (1981). This property means that a high observed value of y likely indicates high public investment $G(a)$. When $\mu_i > 0$, A higher η_y implies that it is easier to change the PDF of large values of y via public spending, compared to the interval with relatively lower values of y. Thus a higher η_y indicates local governments possess greater **self-insurance abilities**, as they are more capable of increasing the probability of achieving higher output levels through the utilization of local productive public spending. In other words, private insurance of local governments squeeze out public insurance of the central government. As a result, the central government offers a less redistributive transfer policy, or equivalently, a larger marginal transfer T'. As a comparison, We can find a corresponding expression of the term $\mu\eta_y$ in the optimal marginal income tax formula with moral hazard. Boadway and Sato (2015) define such term as the efficiency effect, which increases with the tightness of the incentive constraint, and with the marginal influence of output on the responsiveness of the distribution of output to unobservable effort. A higher value of $\mu\eta_y$ contributes to a higher marginal transfer, which means less inter-regional smoothing of fiscal expenditures.

From the above analysis, we summarize that the expression of the optimal marginal transfer naturally shares similar analytical structure with existing literature. The term $\frac{1}{r_i}$ and $\mu_i\eta_y$ in equation (26) separately corresponds to the individual insurance effect and efficiency effect in the expression of optimal marginal labor income tax derived in Low and Maldoom (2004) and Boadway and Sato (2015). The term η in the denominator reflects the semi-elasticity of density function $F(y)$ on G and has a resemblance to the inverse elasticity rule in designing the optimal replacement rate of social insurance in Chetty and Finkelstein (2012).

Information rent. What distinguishes our work from the existing literature is the interplay of various determinants of information rent μ. The level of information rent reflects the cost of keeping the local government revealing their true types. Similar to the interpretation of information rent in Mirrlees taxation, when the information rent is positive (negative), optimal transfer aims to restrain under-reporting (over-reporting) of ability. In other words, the central government intends to encourage (discourage) local investment spending through transfer. Compared to literature with moral hazard and adverse selection, μ captures a broader set of incentives, including the trade-off between different types of public spending and the impact of interregional competition. By decomposing the information rent, we can demonstrate how it influences local government behavior and helps mitigate efficiency losses arising from asymmetric information and competition. The detailed discussion is in Section 3.2.

Equity preference and the tax-sharing system. At last, the social preference of the central government β_i and the retention rate of the final output at the subnational level of governments Ω will influence the optimal transfer policy. Under the Kobb-Douglas production function, the ratio Ω is exogenous and constant, determined by the proportion of tax revenues retained at the local level (so-called retention rate), tax rates, and the capital share in the production function. A high Ω leads to a low marginal transfer level since the tax revenue partially substitutes the redistribution function of transfers. The marginal transfer on output depends only on Ω when the central government can observe the abilities of local governors. [12]

3.2 Decomposition of Multiple Incentives in Information Rent

The information rent μ encompasses multiple types of incentives of local governments induced by uncertainty, interregional tournaments, and fiscal pressure under decentralization. These factors are prominently discussed in the context of fiscal federalism and fiscal union research. Therefore, through a detailed analysis of μ, we can thoroughly examine how these factors should be aligned with or adjusted through the design of transfers, offering a clear decomposition of the incentives involved. Relying on the benchmark model that includes two types of local governments, we can give a clear decomposition of information rent using sufficient statistics.

To simplify the analysis, assume only regions with higher ability care about interregional competition. This means $\chi_H > 0$, and $\chi_L = 0$. Denote by μ_H the information

[12] We discuss the optimal transfer under full information in appendix 6.3.

rent for a high-ability region, and denote by μ_L the rent for a low-ability region. Proposition 2 provides clear decomposition of optimal information rents for both types of regions:

Proposition 2. *When $\chi_H > 0$, $\chi_L = 0$, we can decompose optimal information rents as:*

$$\begin{aligned}\mu_L = &- \underbrace{\beta_L cov_y\left(u_L, \eta_L\right)}_{\textit{Risk-based Social Welfare Multiplier}} \times \overbrace{\widetilde{\varepsilon}_L}^{\textit{Behavioral Elasticity}} \\ &+ \underbrace{\beta_L E_y\left(u_{s,L}\right)\left(1 + \mathcal{T}'\left(G_L\right) - E_y\left(G_L \eta_L\right)\right)}_{\textit{Budget-based Social Welfare Multiplier}} \times \widetilde{\varepsilon}_L \\ &- \underbrace{\chi_H \mu_H \pi_H a_L \Psi}_{\textit{Correction of Interregional Tournaments}} \times \widetilde{\varepsilon}_L\end{aligned} \tag{27}$$

$$\begin{aligned}\mu_H = &- \underbrace{\beta_H cov_y\left(u_H, \eta_H\right)}_{\textit{Risk-based Social Welfare Multiplier}} \times \overbrace{\widetilde{\varepsilon}_H}^{\textit{Behavioral Elasticity}} \\ &+ \underbrace{\beta_H E_y\left(u_{s,H}\right)\left(1 + \mathcal{T}'\left(G_H\right) - E_y\left(G_H \eta_H\right)\right)}_{\textit{Budget-based Social Welfare Multiplier}} \times \widetilde{\varepsilon}_H,\end{aligned} \tag{28}$$

where $\widetilde{\varepsilon}_L$ and $\widetilde{\varepsilon}_H$ are the total elasticity of productive public spending connected to incentive compatibility for two types of regions.[13] $\mathcal{T}'(G_i) \equiv \frac{d\int_y (T(y)+\Omega y) F_y(y|a_i,G_i)dy}{dG_i}$ *is the expectation of the marginal change of ex-post fiscal revenues induced by the change of productive public spending. Ψ is a term related to the externality caused by the high-ability governments' competitive incentives on the low-ability regions.*

Proposition 2 shows optimal information rents for both types of regions are shaped by two groups of items. First is the behavioral term $\widetilde{\varepsilon}_L$ and $\widetilde{\varepsilon}_H$. These elasticities reflect, when local governments receive a marginal change in transfers, to what extent their behavior G will change and thus they deviate from the original IC constraints. Second is a collection of all the remaining terms in (27) and (28). They capture how the deviation from the original IC constraint influences social welfare. Finally, to prevent such deviation and ensure that local governments reveal their true private information, the central government should compensate local governments with a price of μ (information rent).

Since μ_H differs from μ_L only by the removal of the last line of equation (27), we will first discuss the information rent in the low-ability region based on (27). Following that, we will briefly compare μ_H to μ_L.

3.2.1 Information Rent of Low-ability Regions

According to (27), the information rent for a low-ability region is determined by four factors. Despite the behavioral term $\widetilde{\varepsilon}_L$, the other three terms are all the direct effects

[13] We will show its definition and discuss it in Section 3.2.2.

on social welfare as a result of the change in the tightness of IC constraint. Since an information rent is the shadow price of obeying IC condition evaluated through social welfare, we need to transform the behavioral changes represented by behavioral elasticities into corresponding changes in social welfare by multiplying welfare effects, as shown by the right-hand side of equation (27). We will defer the discussion of the behavioral term $\widetilde{\varepsilon}_L$ to the next subsection and concentrate on the remaining terms in the following analysis.

Risk-based Social Welfare Multiplier. First, the behavioral changes of local governments influence social welfare by altering the output distribution, as reflected in the first term on the right-hand side of (27). Since the central government is concerned about the utility of local governments, a marginal deviation from the IC constraint will require the marginal change in the productive public spending (the behavioral effect), which will further impact the output distribution (the risk-based social welfare multiplier). Given that η_L represents the elasticity of the conditional distribution of y_L to the public spending in type-L region, the covariance $cov_y(u_L, \eta_L)$ reflects how a marginal increase in transfers to this region can alter the expected final output to hedge against uncertainties. A higher covariance indicates that the ability to change the distribution is more likely to increase the final welfare. This implies that the regional government can more readily ensure both the consumption of non-productive public goods and private consumption after receiving interregional insurance from the central government[14]. As a result, with a significantly large risk-adjusted welfare effect, the transfer policy does not need to provide excessive subsidies to low-ability regions, which means μ_L should be low when $cov_y(u_L, \eta_L)$ is high.

Here we should also remark the difference of roles between the elasticity term η or η_y in the expression of optimal marginal transfer (26) and the terms related to η in the information rent proposed in Proposition 2. As previously discussed, while η in (26) represents the social insurance consideration, the information rent in (27) and (28) corresponds to efficiency considerations of transfer design. Although the risk-based welfare multiplier is also influenced by the likelihood ratio, it primarily reflects the economic cost of maintaining efficient local public spending. This is achieved by highlighting the social welfare losses resulting from marginal behavioral changes that violate the incentive compatibility (IC) condition. This focus is distinct from the risk insurance function indicated by η and η_y in the optimal transfer formula (26).

A few papers discuss the risk-sharing function of interregional transfers in a fiscal union, such as Dai, Huang, Liu, and Tian (2022); Dashkeev and Turnovsky (2018); Farhi and Werning (2017); Lockwood (1999). Our work explores the role of interregional transfers as a form of insurance against regional economic shocks, where local governments can conduct incomplete self-insurance through productive public investment. The unobservable economic uncertainties for policymakers also induce moral hazard problem in this model. As a result, the central government should pay different information rents to two types of regions. Some studies discussing fiscal insurance against economic uncertainties also stress the impact of information rents(Boadway & Sato, 2015; Castro-Pires et al., 2024; Dyrda & Pedroni, 2022; Heathcote & Tsujiyama,

[14]The correlation between u and η is not necessarily positive. The expansion of G not only increases expected output but also directly affects the budget for non-productive public spending. Therefore, the relationship between G and utility u, which depends on both S and C, is complex.

2021). Most of them focus on taxation and individual income shocks. However, we hardly find any decomposition of an information rent showing how uncertainty shapes the information rent. By contrast, we decompose the information rent term and highlight μ negatively correlates with the risk-based welfare adjustment term, provided that the behavioral elasticity is positive.

Such decomposition of μ helps to separate the behavioral influence of moral hazard from the social welfare influence of pure insurance against risks in the information rent[15]. The correction of behavioral distortions induced by moral hazard and adverse selection is reflected in the behavioral elasticity term $\widetilde{\varepsilon}_L$, and by multiplying the elasticity with the social welfare marginal effects such as $cov_y(u_L, \eta_L)$ we can obtain the welfare cost μ addressing moral hazard and adverse selection. This means that we confine the impact of moral hazard on optimal transfer design into the elasticity terms. We will decompose the elasticity term $\widetilde{\varepsilon}_L$ in the next subsection.

Budget-based social welfare multiplier. Changes in G affect fiscal pressure, which in turn influences public service provision and social welfare, ultimately impacting the optimal information rent. The budget-based social welfare multiplier reflects the effect of relaxing the budget constraint under a decentralized fiscal system. The item $1 + \mathcal{T}'(G_L) - E_y(G_L\eta_L)$ is the marginal change in the expectation of non-productive public spending resulting from the marginal change in the productive public expenditure. This term highlights three ways in which behavioral changes in G_L can affect the provision of S_L: the direct substitution between two types of public spending within the budget, the marginal change in expected transfers, $\mathcal{T}'(G_L)$, and the marginal change in the output distribution, η_L. A change in central transfers can marginally increase local productive public spending. If this significantly enhances the provision of non-productive public goods, as reflected by a high expectation of local residents' marginal utility $E_y(u_{s,L})$, local governments will have a stronger incentive to deviate from their original public spending levels in order to expand public service provision[16]. Therefore, this welfare multiplier is positively linked to the information rent, implying that the central government should provide greater compensation to these regions.

The budget-based social welfare multiplier encapsulates the trade-off between public investment and non-public goods consumption. Early fiscal federalism literature provides prescriptive studies on the composition of governmental public spending (Oates, 1972). However, the discussion about the trade-off between productive public investment and non-productive public services is scarce. Keen and Marchand (1997) argue that interregional competition for mobile capital leads to under-provision of public goods for immobile consumers and over-provision of public productive investment. This finding supports the argument in our work that competition causes efficiency losses by driving excessive spending on G, but they fail to discuss this problem under the fiscal decentralization context. Sacchi and Salotti (2016) finds the political and demographic factors have significant empirical impact on the composition of public spending. Grisorio and Prota (2015) use Italian data and demonstrate that the fiscal decentralization stimulates the provision of public investment while reducing the

[15] However, moral hazard and adverse selection are not separated in this expression, as the effects of these two issues may not be orthogonal.

[16] Recalling that u_s is negatively connected with S, a high $E_y(u_{s,L})$ indicates a low level of S_L.

levels of welfare public spending. This paper offers a theoretical analysis of the optimal composition of local public spending under a decentralized fiscal system. The trade-off between productive and non-productive spending is influenced not only by the tax competition incentives explored in Keen and Marchand (1997), but also by risk-aversion motivations and the asymmetric information structure.

Correction of interregional tournaments. Finally, apart from the endogenous choice of the low-ability governments, the fiscal behavior of the high-ability governments will also generate the fiscal externality on the low-ability regions due to interregional tournaments. The term Ψ summarize the externality caused by the high-ability governments' competitive incentives on the low-ability regions. Denote by $\psi(a_i, G_i, y)$ the proportion of regions with ability a_i among all regions with output y, and $\psi_G(a_i, G_i, y)$ the partial derivative of function $\psi(a_i, G_i, y)$ on G_i. The expression is $\psi(a_i, G_i, y) = \frac{F_y(y|a_i, G(a_i))\pi_i}{\sum_j F_y(y|a_j, G(a_j))\pi_j}$. Then we have

$$\Psi \equiv E_y \left[\frac{\psi_G(a_L, G_L, y)}{\pi_L} \frac{\psi_G(a_H, G_H, y)}{\pi_H} \right], \tag{29}$$

In the career concern model, the central government evaluates local governance abilities through the observation of y. Hence ψ reflects the pooling status of heterogeneous regions after the realization of shocks and how the central government updates its evaluation through the level of y. Since public investment from both two types of regions can affect the composition of regions realizing output level y, ψ_G reflects how the public spending of different regions jointly influences the evaluation process of the central government. It is noteworthy that even if low-ability regions do not care about the promotion, the IC condition prevents them from imitating a high-ability region's behavior. Hence the information rent for low-ability regions should account for the incentives of tournament of the high-ability regions. The third term $\chi_H \mu_H \pi_H a_L \Psi$ thus represents the correction of the externalities caused by the competitive incentive of the high-ability region.

Externalities in the design of fiscal policies have received significant attention in the literature. The most frequently discussed type of externality is the classic spillover effect of public goods, as noted by Berriel et al. (2024); Jacobs and de Mooij (2015); Kaplow (2012). Another category of externality includes fiscal externality, such as the migration induced by fiscal policies, often referred to as "voting with their feet". This kind of externality is well-explored in spatial public economics research, for instance, in the works of Fajgelbaum and Gaubert (2020); Gaubert et al. (2021); Lehmann, Simula, and Trannoy (2014). Additionally, another branch of literature discusses fiscal externalities within the context of political economics. These studies primarily belong to the theories of fiscal federalism (Besley & Coate, 2003; Janeba & Wilson, 2011) and focus on the optimal level of decentralization instead of place-based policies. Equations (27) and (29) clearly demonstrate how externalities arising from interregional tournaments impact Mirrleesian mechanism design, thereby influencing place-based fiscal transfer policies and allowing them to function as Pigouvian taxes. This distinction sets our work apart from previous literature and introduces a novel challenge into the studies of fiscal decentralization.

3.2.2 Behavioral Elasticity: Sufficient Statistic Approach

Next we turn to explain the behavioral elasticities in detail. The elasticity $\widetilde{\varepsilon}_L$ summarizes all channels where transfers affect productive public spending through the first-order (or equivalently, IC) condition of a type-L local government, which is the behavioral effect of the information rent. The elasticity can be decomposed as follows:

$$\widetilde{\varepsilon}_L = [\underbrace{\varepsilon_L^s \frac{E_y\left(u_{s,L}\right)}{G_L}\left(1+\mathcal{T}'\left(G_L\right)-E_y\left(G_L\eta_L\right)\right)}_{\text{Price Channel}} \underbrace{-\varepsilon_L^\eta \frac{E_y\left(u_L\eta_L\right)}{G_L}}_{\text{Distribution Channel}} \overbrace{\underbrace{+\chi_L\Xi(a_L,G_L)}_{\text{Tournament Channel}}}^{=0 \text{ when } \chi_L=0}]^{-1} \tag{30}$$

The first term, $\varepsilon_L^s \equiv -\frac{\partial E_y(u_{s,L})}{\partial G_L}\frac{G_L}{E_y(u_{s,L})}$, is the elasticity of the marginal utility u_s to the productive public spending. $1+\mathcal{T}'\left(G_L\right)-E_y\left(G_L\eta_L\right)$ is the change of expected public good consumption induced by a marginal change in G_L. Since u_s represents the relative price between S and G, the price channel reflects how the shadow price of non-productive public goods is affected by the change of public investment, representing the trade-off on the composition of public spending in the first-order condition (12) of a type-L local government.

The second term $\varepsilon_L^\eta \equiv -\frac{\partial E_y(u_L\eta_L)}{\partial G_L}\frac{G_L}{E_y(u_L\eta_L)}$ is the elasticity of the covariance between the likelihood ratio and utility to the non-productive public goods[17]. As the likelihood ratio η_L represents local governments' abilities of self-insurance, this elasticity reflects how changes in G_L influence the self-insurance incentive through the expansion of public investment. The distribution channel corresponds to the marginal change in the second term of the first order condition of a type-L local government (12). It indicates that the deviation from the efficient public investment levels induced by a variation in transfer funds will also result in the changes in local self insurance abilities. Moreover, the distribution channel suggests that regional economic shocks affect the optimal transfer not only through the risk aversion attitudes and self-insurance abilities in (26), but also by distorting self-insurance behavior due to the incentive effects encompassed by the information rent term. This highlights the dual role of regional shocks in shaping both the risk-insurance function of transfers and the fiscal behavioral distortions shown in Proposition 2.

Finally, the third term reflects the interregional competition channel influencing the behavior of local governments. Since low-ability regions do not engage in the tournament, this part is equal to zero. $\Xi(a_j,G_j)$ is defined by

$$\Xi(a_j,G_j) \equiv \chi_j\int_y \hat{a}(y)F_{yGG}(y\mid a_j,G_j)dy - \chi_j\int_y a_j\frac{F_{yG}^2(y\mid a_j,G_j)}{f^Y(y)}\pi_j dy,\ \ j\in\{H,L\}.$$

It is exactly the derivative of the third term connected to the competitive incentive in (12), representing the marginal change in the career concern term in the first order condition of local governments induced by the marginal increase in G_L.

[17] Since $cov_y(u_L\eta_L) \equiv E_y(u_L\eta_L) - E_y(u_L)E_y(\eta_L)$ and $E_y(\eta_L) = \int_y F_{yG}(y|a,G(a))dy$, we have $cov_y(u_L\eta_L) = E_y(u_L\eta_L)$.

These three terms in the bracket of (30) together capture the direct social welfare impact of a marginal change in G_L. They respectively correspond to the multiple incentives of a type-L local government, as illustrated in the first-order condition (12): the incentives to substitute nonproductive public goods with productive investment, the risk-insurance incentives, and the competitive incentives. The inverse of their sum can be interpreted as a generalized elasticity of the productive public spending G_L with respect to the overall fiscal behavioral changes. Specifically, given the level of marginal deviation from the first-order condition, the elasticity $\widetilde{\varepsilon}_L$ indicates how much the spending G_L should adjust to achieve such deviation. Since the first-order condition of local governments have the same form compared to the IC condition, the elasticity $\widetilde{\varepsilon}_L$ can also be interpreted as the marginal efficiency cost of maintaining the IC condition, while the other terms in (27) represent the economic benefit. To see this, we transform (27) by multiplying both sides by $1/\widetilde{\varepsilon}_L$.

$$\begin{aligned}\mu_L/\widetilde{\varepsilon}_L = &- \beta_L cov_y\left(u_L, \eta_L\right) + \beta_L E_y\left(u_{s,L}\right)\left(1 + \mathcal{T}'\left(G_L\right) - E_y\left(G_L \eta_L\right)\right) \\ &- \chi_H \mu_H \pi_H a_L \Psi\end{aligned} \tag{31}$$

The right-hand side of (31) now represents the direct social welfare benefits of an increase in G_L. The left-hand side becomes the distortion of local behavior due to the deviation from the IC condition, which results from the marginal change in the transfer policy. Optimal information rent must equalize the two sides.

Sufficient statistics are widely used in public finance research. Saez (2001) and Chetty (2009) introduced the method in the optimal taxation theory. Hendren (2016) and Hendren and Sprung-Keyser (2020) propose the policy elasticity in analyzing welfare effects of governmental policies. However, Kleven (2021) questions the feasibility of sufficient statistics under different scenarios. In our model, $\widetilde{\varepsilon}_L$ is a compound elasticity and is related to the comprehensive outcomes resulting from fiscal policy changes. Although this elasticity is difficult to estimate empirically,[18] it is still helpful to use sufficient statistics to offer clear economic insights understanding the optimal design of information rent in Proposition 2.

3.2.3 Information Rent of High-ability Regions

The information rents for the high-ability regions are shown in the equation (28). It is noticeable that the first two terms have similar structures to those in (27). However, the elasticity $\widetilde{\varepsilon}_H$ in (28) encompasses incentives arising from concerns about tournaments. The elasticity $\widetilde{\varepsilon}_H$ is defined as:

$$\widetilde{\varepsilon}_H = [\varepsilon_H^s \frac{G_H}{E_y\left(u_{s,H}\right)}\left(1 + \mathcal{T}'\left(G_H\right) - E_y\left(G_H \eta_H\right)\right) - \varepsilon_H^\eta \frac{G_H}{E_y\left(u_H \eta_H\right)}$$

[18] There are mainly two difficulties in estimating $\widetilde{\varepsilon}_L$: (1) it is a big challenge to extract the information rent from fiscal funds given to localities in reality; (2) $\widetilde{\varepsilon}_L$ represents the behavioral effects of μ_L on the welfare, which can not be equivalently replaced by the behavioral effects of observable changes in G empirically estimated in reality. This is not only because the elasticity should be estimated under the optimal transfer rule rather than prevailing policies, but also due to the empirical difficulties in disentangling the behavioral effects of information rent from the causal effects of other factors on fiscal behavior when investigating the economic outcomes of any transfer policy reform in practice.

$$+ \underbrace{\chi_H \Xi(a_H, G_H)}_{\text{Tournament Channel}}]^{-1}. \tag{32}$$

The three parts exactly correspond to those in the definition equation of $\widetilde{\varepsilon}_L$. What is different is that the tournament term is no longer zero. Any changes in productive public spending in high-ability regions will directly affect the central government's Bayesian updating process, thereby influencing the information rents.

Although there is no correction term of externalities in (28), the central government still needs to address distortions in high-ability regions. First, we can find the competitive incentive is taken into consideration in the behavioral elasticity (32). Besides, by holding the correction term in (27), the spillover effects on the low-ability regions of competitive incentives from the high-ability regions is corrected by transfers. Finally, since the optimal transfer is the weighted sum of both μ_L and μ_H, the correction term $\chi_H \mu_H \pi_H a_L \Psi$ will simultaneously influence the scale of transfers to all regions with the same output levels.

3.3 Optimal transfer with Infinite Types of Regions

Proposition 3 gives the optimal marginal transfer in the case with a continuum types of regions:

Proposition 3. *When the utility function u is additive between the private consumption C and public goods consumption S, and the utility function of S takes the form of CARA, the optimal marginal transfer can be expressed as:*

$$\begin{gathered} T'(y) = E_a \left(\frac{\mu(a)\eta_y(a,y)}{r\beta(a) + r\mu(a)(\eta(a,y)+r)} \right) - \Omega; \\ \Omega = \xi^l \tau^l (1-\alpha) + \xi^k \tau^k \alpha \end{gathered} \tag{33}$$

The optimal marginal transfer shares the same structure as (26) in the baseline case. It is also jointly determined by the information rent μ, the likelihood ratio η, the risk-aversion coefficient, the social welfare weight, and the retention rate of taxation. Besides, we show in Appendix 6.2.3 that the structure of information rent decomposition also holds in the case of infinite regions, which validates those economic insights provided by the decomposition in a more general context. The information rent is determined by a Fredholm integral equation of the second kind, which can only be solved numerically[19]. We utilize (33) in our numerical analysis to fit the fact that there are infinite types of local governments in reality.

4 Numerical Analysis

In this section, we perform numerical simulations of optimal transfer design, quantitatively illustrating the effects of information asymmetry, regional macroeconomic shocks, and interregional competition on the optimal policy. China is selected as a case study for this analysis. Chinese central government established the interregional transfer system in 1995, after the comprehensive reform of tax collection and tax-sharing

[19]We refer to the numerical method proposed by Sachs, Tsyvinski, and Werquin (2020) to solve the integral equation. See Appendix 6.4.2 for detailed discussion.

system in 1994. In the fiscal year of 2023, the most important component of interregional transfers, the general transfers, amounted to about 8.5 trillion CNY, accounting for about 72.5% of total local fiscal revenues according to the official National Government Final Account published by the Chinese Ministry of Finance. Moreover, China faces multiple challenges highlighted in this paper, making it an ideal subject for exploring the reform of transfer policies. By utilizing fiscal data from Chinese county-level governments in 2019, we can approximate the current transfer schedule $T(y)$, calibrate the distribution of ability a and the welfare weight on career concern χ, and simulate the optimal transfer schedule. We also present how career concern, the retention rate, and regional economic fluctuation shape the design of place-based fiscal policies in developing countries like China.

4.1 Data and Parameters

Table 1 collects the main parameters used in numerical analysis.

Some parameters are directly imposed based on readily available information. We adopt the following utility function of a local governor:

$$u(C, S) = \ln C - A\frac{1}{r}e^{-rS}, \tag{34}$$

The utility function of S takes the form of CARA so that we can apply the expression of optimal marginal transfer in equation (26) to simulation. [20] Where A measures the resident's relative preference for public goods consumption S compared to private goods consumption C. We set $A = 0.02$ in our baseline model. For the degree of absolute risk aversion, we set $r = 6$ following Jackwerth (2000). In the production function estimation in Collard-Wexler and De Loecker (2016), the capital coefficient is half of the labor coefficient in China. Therefore, in the production function (4), we set $\alpha = 0.3$. Following Song and Xiong (2023), we set $g = 1 - \alpha$. The annual return rate of one-year treasury bonds is around 3% in 2019, so we adopt $R = 1.03$. According to China's current tax sharing rules and tax rate, we set $\xi^k = 0.5$, $\xi^l = 0.4$, $\tau^k = 0.17$, and $\tau^l = 0.25$.[21] Based on the execution of the central government's fiscal budget during 2019 to 2022, the ratio of transfers to the central government's consumption expenditure as 2/3. Therefore, the share of the central government's consumption to fiscal income, z, is 40%. For governments' preferences, assume that the central government adopts a utilitarian social welfare function, i.e. $\beta(a) = 1$.

We select the remaining parameters to fit Chinese county-level fiscal and economic data. The data on transfers and local government expenditures were manually collected from the final financial accounts of local governments in 2019. We collected variables

[20] This assumption on function form is not restrictive. Yan, Tong, and Wang (2024) prove that as long as the agent's utility function is in the form of expected utility, then the agent's utility function is the constant absolute risk aversion (CARA) utility function.

[21] The top four taxes in China are value-added tax, corporate income tax, excise tax (on 15 kinds of goods) and individual income tax. Since we do not incorporate intermediate goods nor production networks in the model, the value-added tax in China can be viewed as the consumption tax on final goods. Denote by τ^I the average individual income tax rate. Denote by τ^C the average value-added tax rate. We get $C(1 + \tau^C) = (1 - \tau^I)\Phi L + RK$ in reality. This indicates that labor income tax rate in our model satisfies $1 - \tau^l = \frac{1-\tau^I}{1+\tau^C} \approx 1 - \tau^I - \tau^C$) and $1 - \tau^k = \frac{1}{1+\tau^C} \approx 1 - \tau^C$. As firms in our model have no profit, we do not consider corporate tax.

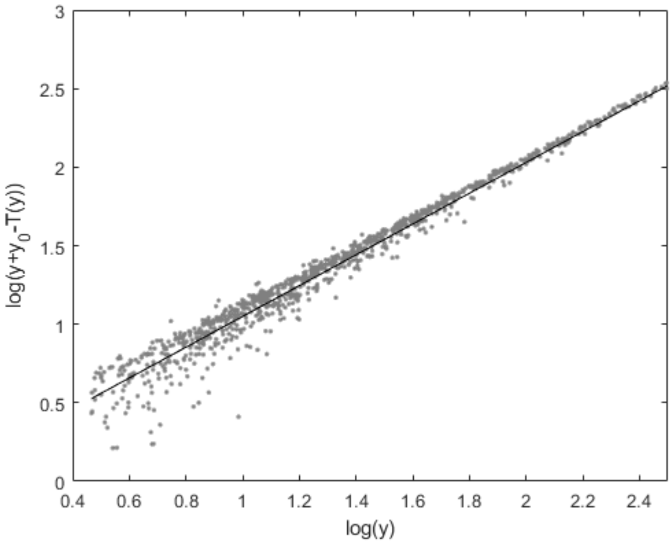

Fig. 2: The fitness of central transfer function

including amounts of transfers, local government's fiscal expenditures, regional output, and other local economic characteristics data of China in 2019 for numerical simulation. Since the labor supply of each region is normalized to 1 in the model, we measure the level of regional output by per capita GDP. 1385 observations were obtained after removing the invalid observations with missing values of some key variables. To avoid the interference of outliers on the results, the local GDP and productive expenditure were further truncated at the level of 5%, and finally we obtain 1119 valid observations.

We first calibrate the current transfer function $T(y)$ in China. To fit the relationship between the central government's transfers and local output in reality, we adopt the following functional form, similar to the form of the income taxation formula discussed in Heathcote, Storesletten, and Violante (2017):

$$T\left(y\right) = y - \phi_1 y^{1-\phi_2} + y_0, \tag{35}$$

where ϕ_1 and ϕ_2 measures the size and progressivity of central transfer. y_0 is the novel parameter compared to the canonical HSV function, which is the lump-sum subsidies to local governments.

We fit the observed data on y and $T(y)$ by the nonlinear least square method and get $\phi_1 = 1.07$, $\phi_2 = 0.02$, $y_0 = 0.66$. This function well fits the relationship between transfers received by local governments and local output in reality. To see this, transform the equation (35) into:

$$\log\left(y + y_0 - T\left(y\right)\right) = \log\phi_1 + \left(1 - \phi_2\right)\log y. \tag{36}$$

Figure 2 presents the relationship between $\log(y)$ and $\log\left(y + y_0 - T\left(y\right)\right)$ in the data (the scattered points) and fitted result (the solid line). We can find that

$\log(y + y_0 - T(y))$ and $\log y$ display an obvious linear correlation. The R^2 under the OLS regression (36) is 0.972. Therefore, the function form in (35) well captures the relationship between central transfer and local output.

As we divide public expenditure into productive expenditure and non-productive expenditure according to its different purposes in the model following Barro (1990), we need to clarify the fiscal expenditure categories in the data. In China, the fiscal expenditure is classified into more detailed groups. Based on whether an expenditure can improve output directly in a short period, We select 8 kinds of general public budget expenditure and sum them up as the proxy of non-productive expenditures[22] .

The local governors' abilities and the relative welfare weights on career concerns are unobservable and require calibration. To capture how abilities determine productivity, we set $\Gamma(a) = a^{0.5}$. This means the marginal influence of a on $\log(A)$ is decreasing, while the marginal influence of the output shock ε is constant. Without loss of generality, assume that abilities and output shocks are normally distributed and independent of each other: $a \sim N(\mu_a, \sigma_a)$; $\varepsilon \sim N(\mu_\varepsilon, \sigma_\varepsilon)$[23]. We calibrate χ according to the relationship between transfer, productive public spending, and local GDP in China. Specifically, using the first-order conditions (12) of local government decisions, the characteristics of ability a's distribution μ_a, σ_a, we can obtain the relationship between a and χ at each observed combination of $\{y, T(y), G\}$. Iterate χ until the resulting a follows a normal distribution with a mean of μ_a and a variance of σ_a^2.

Subgraph (a) of figure 3 illustrates the relationship between regional calibrated abilities a and levels of investment public spending. Under the current transfer function, per capita investment public spending and local governors' abilities are negatively correlated. This is because compared with regions with low abilities, local governments with high abilities do not require too much productive public spending to achieve an expected output. In reality, regions in China that are supposed to have more advanced governance abilities always spend more on non-productive public goods, or so-called basic pubic services, including local education, medical expenditures and social securities undertaken by local governments. These regions include the so-called 'tier-1 cities' like Beijing, Shanghai, Shenzhen, etc.

Subgraph (b) displays the relationship between χ and a. With the improvement of ability, local government's utility weights on career concern show an upward trend, but for areas at the two ends of the distribution, χ gradually decreases with a. Compared with high-ability counterparts, it is difficult for low-ability governors to win over inter-regional competitions. Therefore, they lack the interest in valuing the central government's expected evaluation of ability. This possibly explains the upward trend of $\chi(a)$. The downward sloping $\chi(a)$ curve among extremely high-ability governors may result from a lack of strong opponents or a low pressure in promotion competition. For extremely low-ability governors, they have strong motivations to be "lifted out of poverty", an indicator of outstanding poverty governance performance. Hence we see higher $\chi(a)$ with lower a among these regions.

[22]The 8 kinds of general public budget expenditure include general public service expenditure, national defense expenditure, public security expenditure, education expenditure, culture, sports, tourism and media expenditure, health expenditure, urban and rural community expenditure, and housing security expenditure.

[23]It is noteworthy that with the normal distributions of a and ε, the TFP A should be subject to a right-skewed distribution.

Table 1: The parameter values used in baseline simulation

Variables	Notations	Values	Source
Share of capital income	α	0.30	Collard-Wexler and De Loecker (2016)
Retention rate of labor income tax	ξ^l	40%	to match the corporate income tax sharing ratio
Retention rate of capital income tax	ξ^k	50%	to match the value-added income tax sharing ratio
Labor income tax rate	τ^l	25%	the statutory corporate income tax rate
Capital income tax rate	τ^k	17%	the statutory value-added tax rate
Share of central government consumption	z	40%	to match the share of national defense in the central government's expenditure
Absolute risk aversion coefficient	r	6	Jackwerth (2000)
Gross return of capital	R	1.03	the annual return rate of one-year treasury bonds
Mean of abilities	μ_a	2.4988	to match the distribution of G and y in data
Variance of abilities	σ_a^2	0.4415	to match the distribution of G and y in data
Mean of output shocks	μ_ε	0.1960	to match the distribution of G and y in data
Variance of output shocks	σ_ε^2	0.0661	to match the distribution of G and y in data

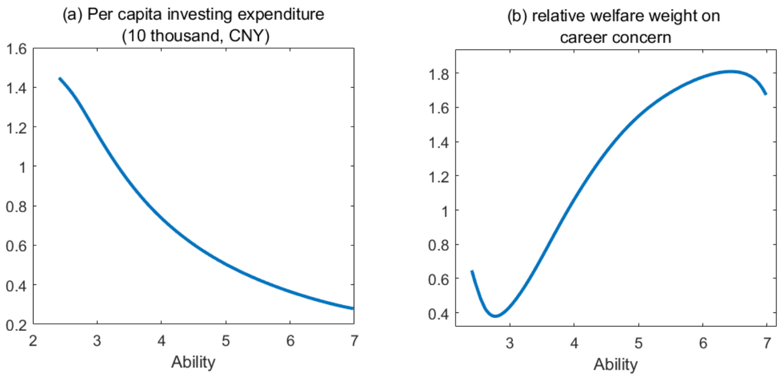

Fig. 3: The calibration of χ and a

4.2 Optimal transfer

Under the parameters in Table 1, we combine the fixed-point algorithm as in Mankiw, Weinzierl, and Yagan (2009) with the way to solve the integral equation in Sachs et al. (2020) to solve the optimal transfer function. Panel (b) of Figure 4 shows that, in terms of scale, the optimal per capita transfer is higher than the current per capita transfer in low GDP regions and lower than the current transfer level in high GDP regions. To illustrate this result, recall that the central government might deduce a low-ability governor behind a low regional output. Hence the regional transfer should be high enough to ensure the stable provision of public goods in these areas under economic uncertainty. However, the formula-based transfer scheme in China hardly considers regional economic fluctuation. Compared with the optimal transfer, the current transfer to low-output regions should increase. Our results coincide with Tochkov (2007), who pointed out that rich provinces in China were better insured against province-specific revenue shocks than poor provinces during the 1952–2001 period.

The optimal transfer function displays an inverted U-shaped pattern. The optimal marginal transfer in panel (a) turns from positive to negative as output increases. The explanation for the ascending phase of the optimal transfer rule (below 55 thousand CNY in the figure) is that, in the face of uncertainty, regions with such low per capita GDP are more likely to provide insufficient productive public spending. One reason is the low returns on public investment in these regions. Another consideration is that a high level of productive spending (G) may increase their risk exposure, as it directly reduces resources available for non-productive public services. Therefore, the central government sets transfers increasing with outputs so that these governments are encouraged to enlarge productive public spending. In this way, both the central government's tax revenues and local output can be stimulated.

For local governments with a higher per capita GDP (over 55 thousand CNY in the figure), the optimal transfer curve turns to decline. This is because local governments with higher per capita GDP tend to have higher abilities, and these regions have strong self-development motivations. Even without transfers, they can spontaneously invest in infrastructures, thus increasing the probability of achieving higher output. A higher output not only helps in obtaining a better evaluation from the central government but also indirectly improves the level of public service. This means that the central government can reduce the gap in public services by reducing transfers to high-income regions. Additionally, low transfers to regions with high output levels can be seen as a correction mechanism for interregional competition. A higher output would result in fewer transfer funds, serving as a penalty for focusing too heavily on economic performance.

We also draw the information rent curve $\mu(a)$ in panel (c) to inspect what drives the shape of optimal marginal transfer. The information rent primarily shows a descending trend as abilities increase, similar to the optimal marginal transfer curve with per capita GDP, but is slightly different by following a U-shaped pattern in the middle of the range. Therefore, for regions with low to medium output levels, the shape of the information rent is align with the optimal marginal transfer.

To clearly see the behavioral impact of optimal transfer rule on the provision of local public goods, Figure 5 compares fiscal expenditure structure of local governments under current and optimal transfer. We can find that the low-ability regions spend more on productive public spending under the optimal transfer rule, verifying the stimulation effect of the increasing transfer schedule. Non-productive public goods in all regions increase obviously, resulting from the effective insurance against uncertainties provided by optimal transfers.

The optimal transfer also serves effectively as interregional insurance. To show how optimal transfer reduces the fluctuation of regional fiscal expenditures, we compare the changes in coefficient of variance (CV) of two kinds of fiscal expenditure after the implementation of the optimal transfer schedule in China. The CV of per capita local investment public spending slightly decreases as the ability increases in panel

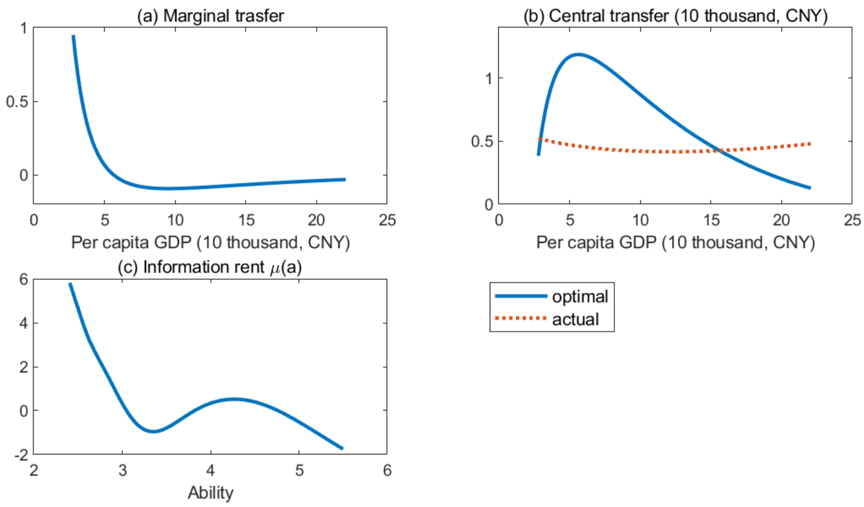

Fig. 4: Optimal per capita central transfer

(a), while the CV of public service expenditure per capita decreases sharply from 1.51 to 0.33. Figure 6 displays the influence of adopting optimal transfer on fluctuations of regional output. The vertical axis denotes the standard deviation of future output given the ability type of a local governor. Obviously, the optimal transfer effectively reduces the fluctuation of local output.

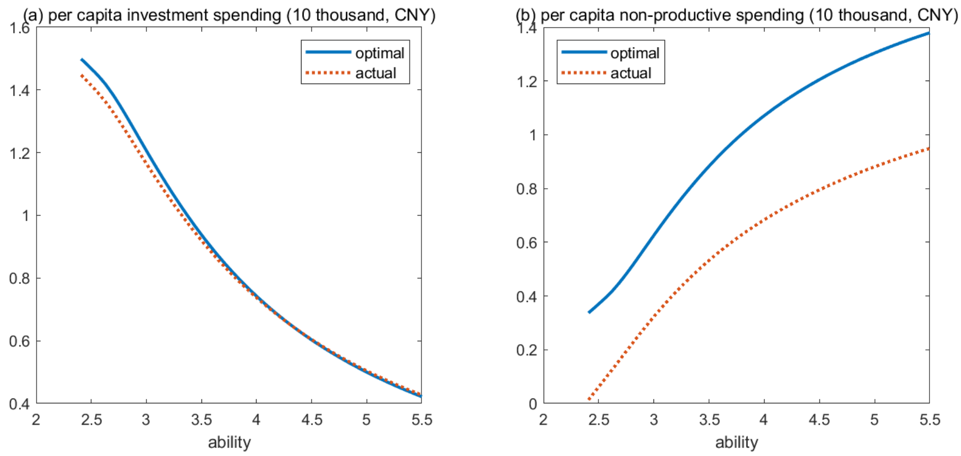

Fig. 5: The distribution of optimal and current local governments' expenditures

Note: The coefficients of variation for G are 0.39 and 0.4 separately under the optimal and actual transfer. The coefficients of variation for the conditional expectation of S are 0.33 and 1.51 separately under the optimal and actual transfer.

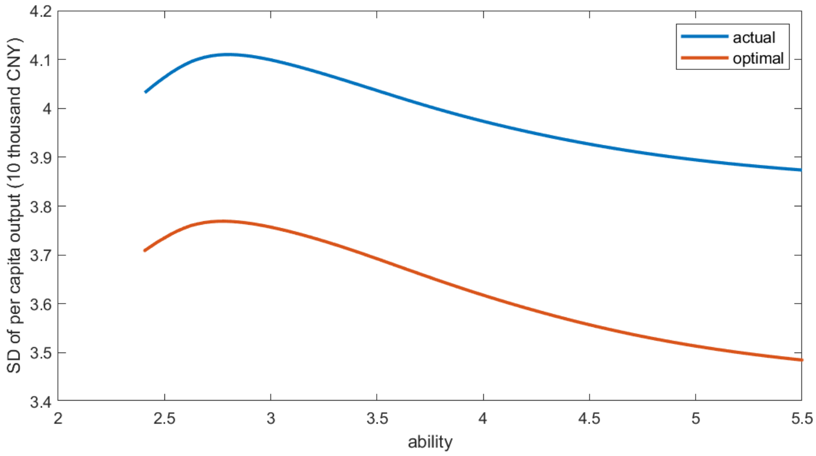

Fig. 6: Output fluctuation under current and optimal central transfer

Adopting an optional transfer can also improve efficiency. The scale of total fiscal transfer will be increased by 13.44%, corresponding to a considerate improvement in production efficiency and therefore total tax revenue.

4.3 Influences of Information Asymmetry

As discussed at the beginning of this paper, we argue that the information asymmetry is essential to the optimal transfer design. To see how introduction of information friction quantitatively changes the design of optimal transfer, we compare the results of full information with incomplete information in Figure 7. In the case of full information, the central government can observe both the ability and the investment expenditure of each local government. Therefore, the optimal transfer is a function of both output and ability. There is no competition induced by career concern since the central government can directly observe governance abilities[24]. Panel (a) of Figure 7 shows that the incorporation of information friction significantly reduces central transfer at all output levels. As the budget for transfers is constrained by the nationwide tax revenues related to total economic output, the decrease in transfers across all regions highlights considerable output decline and efficiency losses induced by information frictions.

The shape of optimal transfer also changes. In panel (b), marginal transfer over local output under full information is negative. This is because the central government, knowing local governments' abilities, can assign a specific transfer schedule to each type of local government. After the realization of economic shocks, the central government can easily deduce the magnitude of the shocks from the observed output and provide accurate social insurance for each region. Thus, the negative marginal transfer in panel (b) represents such full insurance schedules.

[24]The derivation of optimal transfer under full information can be found in Appendix 6.3.

In contrast, with information frictions, the sign of the optimal marginal transfer first becomes positive and then negative as output increases, leading to an inverse U-shaped pattern in the central transfer curve. This can be attributed to two reasons related to asymmetric information. First, due to the pooling of regions with different abilities, the full insurance is infeasible and transfers for low-output regions should serve as dual roles: insurance to regions with high levels of G but experiencing negative shocks, and incentivizing regions with high abilities but low levels of G. This complicates the sign of optimal marginal transfer. Second, the information asymmetry also creates rooms for interregional competition for promotions. As the low-output regions have large scale of public spending, a large amount of transfers to these regions as in the first best case is no longer efficient since this may encourage radical public investment among these regions, resulting in significant negative externalities for other regions that are concerned about promotions. We will discuss the insurance and competition factors later in Section 4.4.

Recall that in panel (a) of Figure 5, a local government's investment spending G still negatively correlates with the local governor's ability a under optimal transfer. To explain this result, we compare the per capita investment in the baseline model with that under optimal transfer when the central government has full information in panel (c) of figure 7. Even in the case of full information, optimal $G(a)$ negatively correlates with the local governor's ability a. The central government can equalize public goods consumption across regions by specifying different transfers to regions with different output and abilities, as in panel (d) of figure 7. However, unlike the public goods $S(a, y)$), which is fully insured through transfers, residents' consumption $C(y)$ only depends on local output, which means it cannot be fully insured in tandem with S. As a result, optimal transfer under full information still requires low-ability regions to promote local output through high levels of investment spending. Such a mechanism still exists in our baseline simulation. By contrast, due to incomplete information, two new mechanisms are noteworthy in shaping $G(a)$. First, an optimal transfer schedule could only alleviate instead of eliminating inter-regional competition. Therefore, local governors with low abilities still have the incentive to gain a better evaluation by the central government, as in Song and Xiong (2023). Second, current transfer policies in China lack support for low-output regions. Thus low-ability governors make insufficient efforts to promote output due to the worry that a high level of G can expose them to large output fluctuations. Therefore, an upward-sloping transfer curve, the optimal one, can exactly provide insurance for regions with lower abilities to increase G and thus to enhance their output.

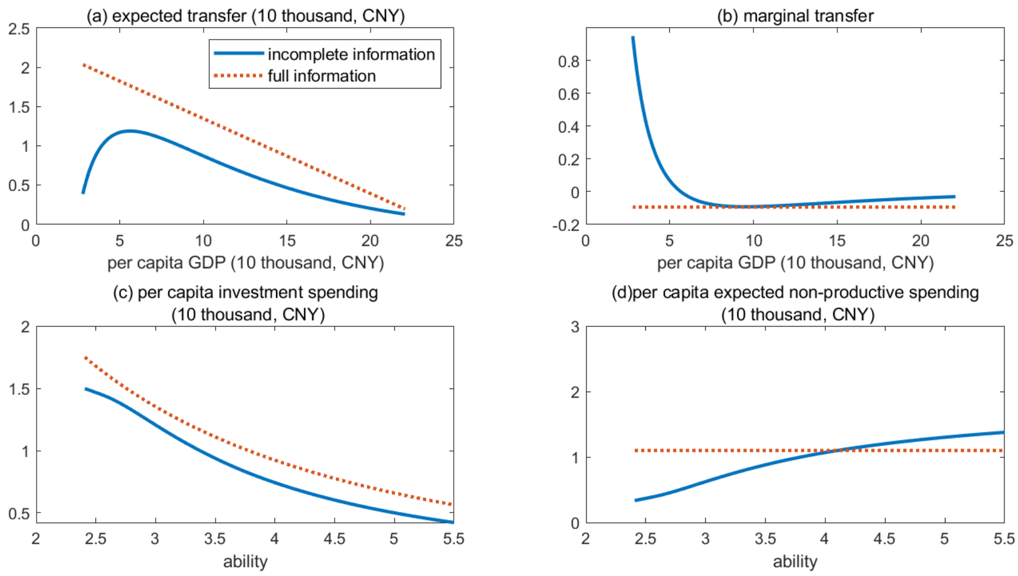

Fig. 7: A comparison of fiscal expenditure under different information structure

4.4 Influences of Risks and Career Concerns

From Figure 7 we learn that introducing information asymmetry can reverse the sign of optimal marginal transfer in low-output regions. It can also greatly reduce the absolute value of the optimal marginal transfer in the high-output regions. The frictions induced by asymmetric information in this paper are threefold: (1) a standard Mirrleesean private information (adverse selection) friction, as local governors' abilities are unobservable by the central government. (2) a moral hazard friction, where local productive public expenditures and economic shocks are unobservable by the central government. (3) an externality friction, where the central government has a corrective motive on the interregional competition behavior arising from local governments' career concerns. While the first friction has been emphasized in early studies like Lockwood (1999), the latter two were seldom examined in the literature on fiscal decentralization. In this part, we numerically present the impacts of parameters corresponding to the moral hazard friction and externality friction through comparative static analysis and emphasize the significance of various considerations in reforming transfer policies.

1. The impact of regional economic fluctuations

Regional economic fluctuations are the source of the moral hazard friction. As σ_ε^2 measures the extent of risks, Figure 8 illustrates the optimal central transfer at various values of σ_ε^2. The three curves correspond to scenarios where σ_ε^2 represents the realistic value (0.0661), a high-risk value (10% higher than the realistic value), and a low-risk value (10% lower than the realistic value).

Since increased σ_ε^2 leads to greater fluctuations in local output, the transfer policy should take a more active role in hedging against economic shocks. Thus it is natural to observe that the optimal marginal transfer in panel (b) of Figure 8 decreases as the risk increases. Specifically, from panel (d) we observe that η_y in equation (26) gets smaller because a higher risk makes it harder for local governments to stabilize their output via self-insurance public spending. This produces a lower marginal transfer curve over local output.

Apart from the pure insurance consideration, the increase in risks also alters the incentives of local governments. The information rent curve $\mu(a)$ becomes flatter, as displayed in panel (c). We observe a significant change at the left tail of the ability distribution, while changes in information rent across the rest of the distribution are trivial. As shown in Figure 5, low-ability regions allocate the largest scale of expenditures to productive investments, making them particularly vulnerable to increased economic risks. Additionally, the fiscal behavioral changes in these regions are likely to be more significant due to their high levels of public spending, which is exactly what the information rent aims to address. For low-ability regions, such changes lead to lower marginal transfer in low-output ranges as the information rent dominates the shape of the marginal transfer among the low-ability interval. However, for high-ability regions, the shifts in information rents are insufficient to counterbalance the decline in η_y, so we still witness a decrease of marginal transfer in high-output regions in panel (b).

Moreover, regional economic fluctuations also impact regional competitions. To see this, we can find that the optimal transfers are higher in medium- and high-output areas in panel (a) of Figure 8 under lower economic fluctuations. Although transfers as rewards for high-output regions may intensify interregional economic competition and potentially crowd out non-productive fiscal expenditures in these regions, the resulting reduction in economic uncertainty may offset these effects. Consequently, these regions may still experience less exposure to the risk of insufficient provision of non-productive public goods, even if they expand their public expenditures G. For the central government, its focus shifts from insurance considerations to encouraging the expansion of public investment in the design of transfers. Consequently, there is less emphasis on inter-regional competition and risk-sharing when designing optimal transfers with lower economic uncertainty[25].

[25] Theoretically, we proved in Corollary 2 in the appendix that when the local productivity shock ε approaches 0, interregional insurance and economic competition have minimal impact on information rents across all regions.

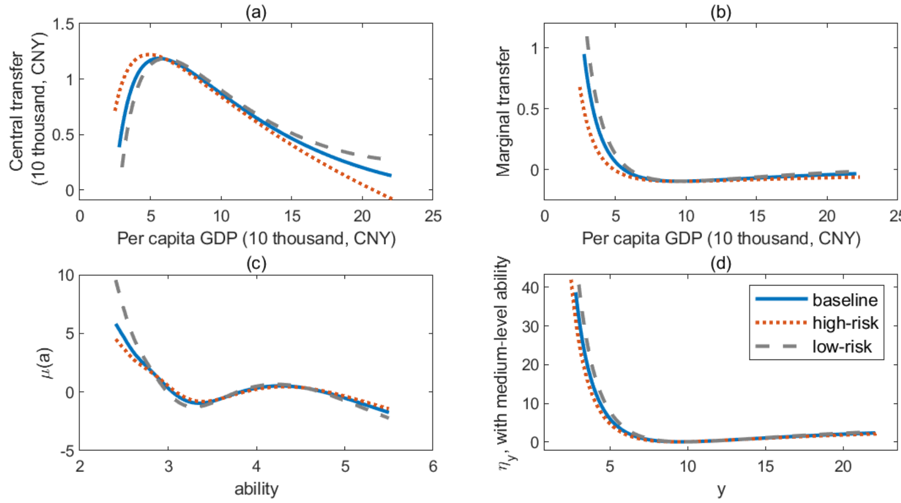

Fig. 8: Optimal transfer under different magnitude of risk

Overall, inter-regional competition necessitates that the optimal transfer may sacrifice certain social outputs to correct the distortions in local government expenditure caused by promotion incentives. This, in turn, affects total social welfare and overall output levels. Greater regional economic fluctuations require that the optimal transfer are supposed to achieve a higher degree of risk-sharing and address heightened concerns about regional competition.

2. The impact of career concerns

The promotion incentive for local governments introduced in this article distinguishes it from previous literature on fiscal decentralization and optimal taxation. Intuitively, magnifying χ for all local governors has two impacts. First, it amplifies potential local governors' utility gains or losses from joining economic competitions and encourage higher investment spending. Second, high-ability governors face greater career concerns and thus experience more pronounced negative externalities from interregional competition, particularly stemming from the high public spending of low-ability regions. The two impacts complicate the changes of optimal transfer.

Figure 9 shows the optimal transfer as the weight assigned to local career concerns varies. The solid line represents the baseline scenario, whereas the dotted line illustrates the condition in which we decrease χ by 20% in each region. The dashed line represents the scenario in which we enhance χ by 20% in each region.

In panel (a) of Figure 9, When all local governments assign lower welfare weights or pay less attention to the governor's career concerns, the optimal marginal transfer decreases. This is because with lower externalities, the motive of the policymaker to correct externalities diminishes. However, since the lump-sum part of optimal transfer increases, we see in panel (b) that optimal transfer increases at low and medium-output levels but decreases at high-output levels.

The increase in the lump-sum part of transfer under weaker career concerns stems from an improvement in efficiency. Notably, we observe an increase of 2.01% of the total transfer amount after reducing χ by 20% from the baseline case, which indicates that reducing career concerns improves fiscal efficiency since the total transfer takes a constant share of the overall output. To explain this result, when career concerns are strong, local governors tend to overspend on investment. Thus, the optimal transfer should correct this distortion in fiscal choices at the cost of reducing economic efficiency.

It is notable that while the optimal marginal transfers under a higher risk and a lower career concern level both decrease compared to the baseline case, the absolute values of optimal transfer under these two cases are slightly different. In panel (a) of Figure 8 we see fewer central transfers to medium-output regions with higher risks compared to the baseline. However, there should be higher transfers to these regions in the scenario of low career concern levels, as shown in panel (b) of Figure 9. This is because a high risk reduces total economic output but a lower career concern will improve it, and thus the lump-sum transfers in these two cases vary as shown in Table 2.

The information rent curve in panel (c) gets flatter across local output when the nationwide levels of career concern decrease. Again, the changes in information rents are most drastic at the left tail of the ability distribution, where the information rent for extremely low-ability regions gets lower. Besides, the information rent for extremely high-ability regions also obviously becomes higher and closer to zero.

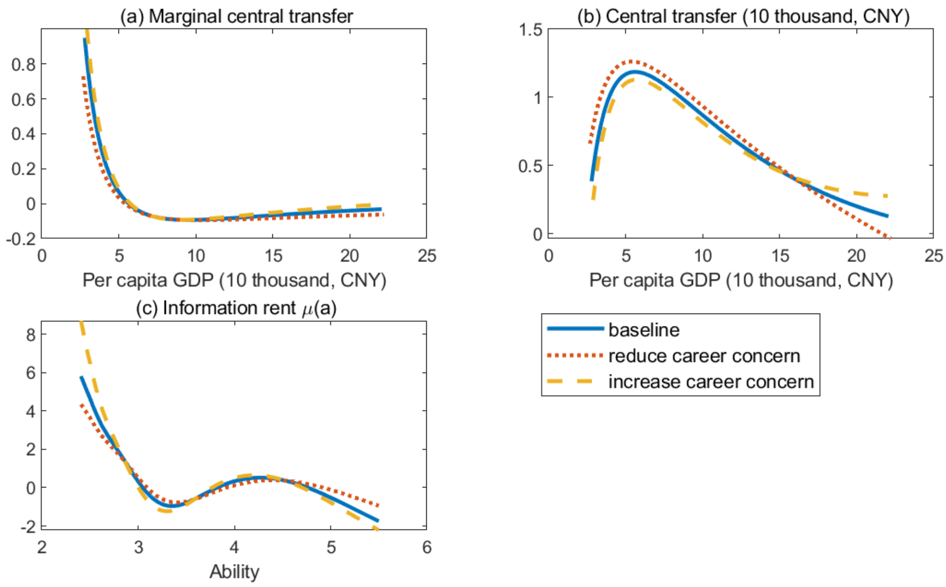

Fig. 9: Optimal transfer under different χ

Table 2: Change of total and lump-sum transfer

	baseline	high risk	low risk	high career concern	low career concern
Percentage change of total transfer (%)	0	- 2.57	2.53	- 1.99	2.01
$T(\underline{y})$ (10 thousand, CNY)	0.38	0.71	0.20	0.25	0.66

It is also remarkable that in the mechanism design research, the optimal mechanism can help principals to infer true types of agents. This raises our interest in exploring how optimal design enables the central government to reassess the governance abilities of local governments, a key question with significant policy implications in practice. To clarify how optimal transfer affects the career concerns of various local governors, Figure 10 illustrates the local government's expectations regarding the central government's evaluation of themselves at different ability levels. Within the major part of the ability distribution (where $a < 4.5$), the expected evaluation from the central government for a type-a local governor under optimal transfer is significantly lower than that under the current transfer system. This suggests that optimal transfer reduces the ex-ante career concerns for most local governments.

Notably, as illustrated in Figure 10, the anticipated evaluation of ability in low-ability regions negatively correlates with the actual abilities of local governors. Recall that we clarified in the previous subsection that $G(a)$ is decreasing in a under optimal transfer. The reason is that regions with significantly low abilities can still achieve high output due to their high public investment level (shown in panel (a) of Figure 5). Consequently, these regions will be pooling with those high-ability regions, making it difficult for the central government to differentiate between them. As a result, local governors with markedly low abilities tend to expect a higher evaluation from the central government compared to regions with relatively higher abilities.

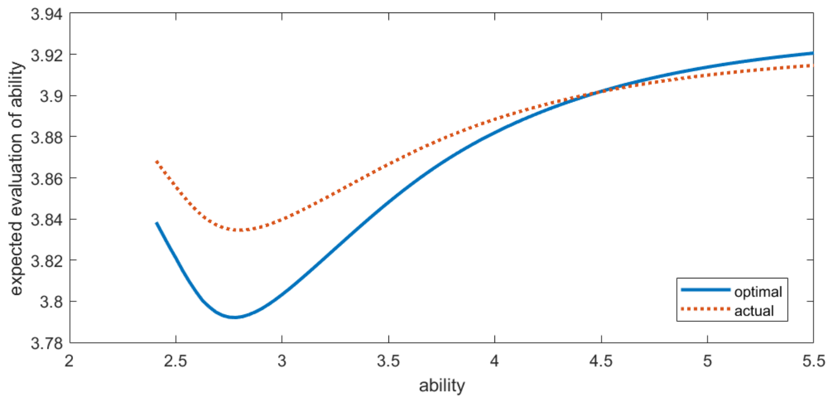

Fig. 10: Expected evaluation of ability from the central government

4.5 Discussion

In the baseline model, we simplify our analysis by holding tax-sharing rates and social welfare weights constant. These parameters influence the extent of fiscal decentralization or the equalization consideration and consequently affect the design of transfers. In this part, we first numerically illustrate the optimal transfer under different values of the retention rate. Next, we compare the optimal transfer under varying welfare weights assigned to local utilities by the central government, reflecting its equity considerations in designing redistributive transfers.

1. The impact of fiscal decentralization.

An increase in the retention rate alleviates the fiscal pressure on local governments by directly enhancing their fiscal revenues. Regions with heterogeneous abilities are confronted with various levels of fiscal gaps between expenditures and revenues they retain. Thus altering Ω would lead to various behavioral responses in local public expenditures, affecting the optimal design of transfers.

Figure 11 illustrates the optimal central transfer at various retention rates of tax income. The three curves correspond to different scenarios: the solid curve represents the realistic retention rate ($\Omega_0 = 0.0955$), the dot-dashed curve depicts a high retention rate ($\Omega = 1.1\Omega_0$, which is 10% higher than the realistic value), and the last curve shows a low retention rate ($\Omega = 0.9\Omega_0$, which is 10% lower than and realistic value).

The numerical results indicate that an increase in the retention rate of distribution necessitates a transfer policy that provides greater support to low-GDP areas. The reason can be explained as follows: as the retention rate rises, the marginal increase in retained local fiscal income for low-GDP areas is less significant compared to high-GDP areas. Therefore, high-GDP areas benefit more from the retention rate change. Then, for the central government, it is optimal to increase transfers to low-GDP areas out of the interregional equity concern.

For regions with high GDP, an increase in retention rates enhances the output returns of local governments and promotes productive public spending. Consequently, transfers should be reduced due to the substitutive relationship between transfers and tax revenues shared with the central government in financing local expenditures.

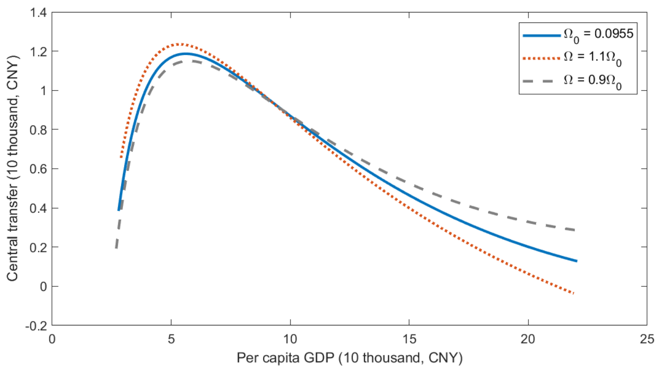

Fig. 11: Optimal transfer under different Ω

2. Alternative social preferences

We have obtained results assuming the central government is utilitarian, which is the most common assumption in the literature. For alternative social preferences, we adopt the following Pareto weight function:

$$\beta(a) = \frac{\exp\left(-\theta a\right)}{\int_{\tilde{a}} \exp(-\theta \tilde{a}) f^A(\tilde{a}) d\tilde{a}}, \tag{37}$$

where θ controls the central government's taste for redistribution. When $\theta = 0$, we get a utilitarian social welfare function with equal Pareto weights on all local governments. A higher θ implies a stronger redistributive preference. As a comparison to Heathcote and Tsujiyama (2021), we choose $\theta = -0.5$ and 1 under a weaker redistributive motive and a stronger redistributive motive case separately.

Panel (a) of Figure 12 plots optimal marginal central transfer profiles for $\theta \in \{-0.5, 0, 1\}$. A stronger redistributive motive results in an upward shift of the optimal marginal central transfer, denoted as $T'(y)$, while the overall shape of $T'(y)$ remains unchanged. This finding contrasts with the results presented in Heathcote and Tsujiyama (2021), which indicate that the direction of the slope is inverted as θ transitions from -0.5 to 1. Panel (b) illustrates the expected central transfer for various regions based on different social preferences. For the lower 80% of the central government's ability, a greater inclination towards redistribution necessitates a higher expected central transfer to these areas. Overall, Figure 12 implies the central government with a stronger redistributive motive increases expected transfers to low-ability regions at the cost of efficiency.

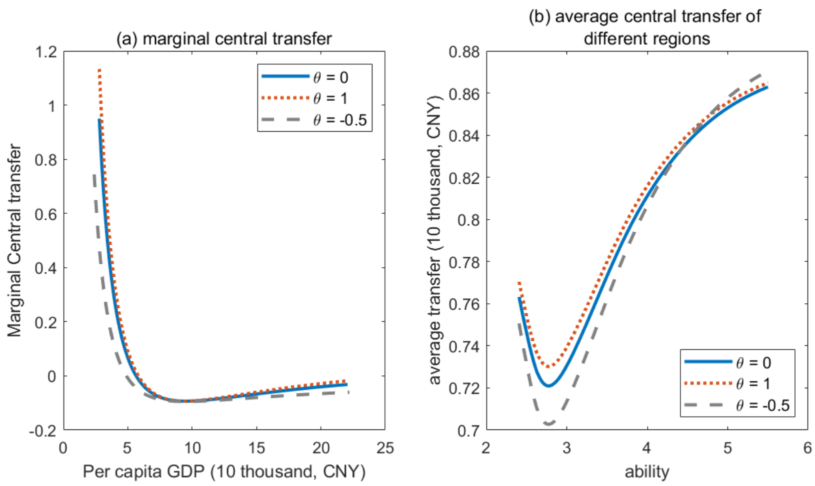

Fig. 12: Optimal transfer under alternative social preference

5 Conclusion

This article presents a comprehensive framework for examining the optimal design of interregional fiscal transfers under incomplete information about local heterogeneities. Using a Mirrleesian principal-agent model, we incorporate regional heterogeneity and idiosyncratic shocks to local output, enabling an analysis of transfers' dual roles in providing interregional insurance and incentivizing truth-telling fiscal behavior of local governments. In addition, we incorporate the tournament mechanism among regional governments into this framework by referencing the career concern model.

Our work thus contributes to the critical practical issue of fiscal decentralization by investigating how to allocate intergovernmental transfers based on local indicators observable to the central government. These indicators are influenced not only by local heterogeneity, which is the root of interregional disparities, but also by exogenous unintended disturbances and endogenous local fiscal choices. Furthermore, this paper contributes to the theoretical resolution of the Mirrleesian mechanism design problem by addressing challenges such as adverse selection, moral hazard, and career concerns through the decomposition of information rent using sufficient statistics.

The optimal transfer in our paper is determined by: the information rent resulting from moral hazard and adverse selection, risk attitudes and self-insurance abilities of local governments, the central government's targets, and other parameters related to the tax sharing system. Specifically, beyond the canonical role of necessitating the public risk insurance, we further analyze the incentive impact of output shocks on optimal transfer design by decomposing information rent using sufficient statistics. This decomposition highlights two key channels through which the risk factor influences optimal information rent: it alters local fiscal expenditure incentives and affects social welfare through tightness of IC constraint. The decomposition also elucidates the effects of competition and fiscal pressure on transfer design.

We use the Chinese county-level data to calibrate key parameters that determine critical distributions, including local economic shocks, local governance abilities, and the weights representing the degree of local governors' career concerns. These parameters are frequently discussed in literature on fiscal decentralization and yardstick competition, while lack quantitative estimation. Based on calibration results, we find that compared with the realistic policies in China, the optimal policy suggests increasing the transfer for regions with low per capita GDP, reflecting its interregional insurance function. The optimal transfer policy can effectively mitigate local economic risks while enhancing the provision of non-productive public goods, such as education, healthcare, and public security expenditures that are highly valued by residents. In this way, our work offers a feasible and practical blueprint for reforming existing transfer policies in countries like China.

Our analysis underscores the quantitative influence of various factors on the design of optimal transfers. The introduction of asymmetric information reverses the sign of the optimal marginal transfer, contrasting with the negative optimal marginal transfer under the full-information case. Therefore, neglecting the information aspect can result in a significant deviation from the optimal transfer design proposed by this paper. Additionally, while an increase in risk and a decrease in career concern produce similar variations in the marginal transfer curve, resulting in a decrease in the marginal transfer, the amounts of optimal transfers differ significantly between these two scenarios due to their contrary impacts on social efficiency.

To conclude, this article develops a unified framework to explore how the central government redistributes fiscal funds based on local endogenous indicators within an asymmetric information environment. It necessitates the multiple functions of interregional transfers, such as addressing both adverse selection and moral hazard issues, and correcting externalities induced by the interregional tournament.

While our model exclusively focuses on information asymmetry and interregional competition by abstracting from frictions caused by household mobility and tax rate competition, one can extend our framework to address these issues in designing place-based fiscal policies. As governments' debts also provide some insurance, an intriguing avenue for future research is to extend this model in a dynamic environment to address local governments' decisions under a richer set of policy instruments.

6 Appendix

6.1 Supplementary Tables and Figures

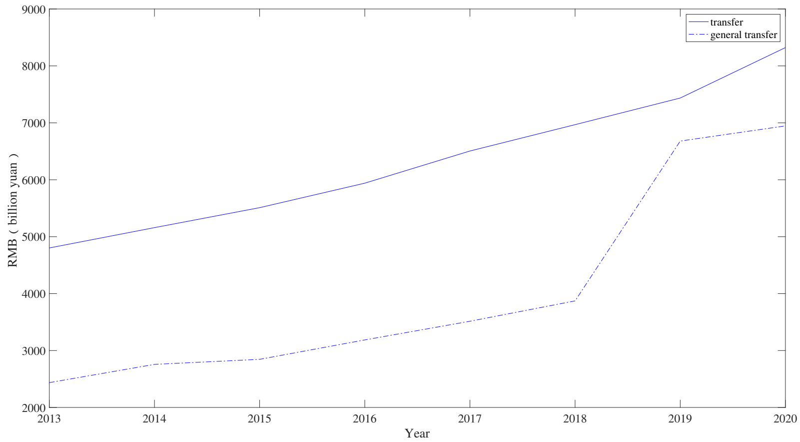

Fig. 13: China's transfers system

Data source: the ministry of finance of the People's Republic of China: financial statements. The solid line represents total fiscal transfers from the central government to provincial-level governments, while the dashed line shows the general transfer, the main component of China's transfer system. The surge in general transfers in 2019 is the result of a reform that restructured transfer items.

Table 3: Inter-regional Disparity and Flypaper Effect of Latin American Countries

	2000	2001	2002	2003	2004	2005	2006	2007
Argentina								
coefficient of variation of GDP per capita	0.70	0.69	0.84	0.77	0.76	0.77	–	-
Correlation between GDP per capita and sharing revenues	0.23	0.21	0.36	0.29	0.25	0.23	–	–
Bolivia								
coefficient of variation of GDP per capita	0.27	0.28	0.28	0.29	0.35	0.49	0.49	0.55
Correlation between GDP per capita and sharing revenues	–	0.71	0.72	0.78	0.81	0.76	0.68	0.71
Brazil								
coefficient of variation of GDP per capita	–	–	0.44	0.54	0.54	0.54	0.54	0.53
Correlation between GDP per capita and sharing revenues	–	–	0.03	-0.22	-0.30	-0.30	-0.29	-0.31
Correlation between GDP per capita and other transfers	–	–	-0.17	0.06	0.41	0.35	0.39	0.40
Mexico								
coefficient of variation of GDP per capita	1.14	1.17	1.16	1.24	1.40	1.40	1.57	1.40
Correlation between GDP per capita and sharing revenues	0.51	0.57	0.46	0.58	0.64	0.59	0.62	0.57
Peru								
coefficient of variation of GDP per capita	–	–	–	–	0.60	0.61	0.69	0.65
Correlation between GDP per capita and sharing revenues	–	–	–	–	0.19	0.72	0.79	0.80

Source: Martinez-Vazquez and Sepulveda (2011).

6.2 Proofs

6.2.1 Optimal Marginal Transfer with Two Ability Types

Define $\mathcal{T}'(G_i) = \frac{d\int_y (T(y)+\Omega y)F_y(y|a_i,G_i)dy}{dG_i}$, then by equation (8), we have

$$\int_y S_L F_{yG}(y \mid a_L, G_L)dy = \mathcal{T}'(G_L) - E_y(G_L\eta_L). \tag{38}$$

The Lagrange function of the optimization problem is presented in (39).

$$\begin{aligned}
&L = \textstyle\sum_i \beta_i \left(\int_y u(S(y,a_i),C(y))F_y(y \mid a_i, G(a_i))\pi_i dy\right) + \\
&\lambda(\textstyle\int_y \Gamma y f^Y(y)dy - \sum_i G(a_i)\pi_i - \sum_i \int_y S(y,a_i)F_y(y \mid a_i, G(a_i))dy\pi_i \\
&+\gamma\left(\textstyle\int_y C(y)f^Y(y)dy + \sum_i \int_y S(y,a_i)F_y(y \mid a_i, G(a_i))dy\pi_i + \sum_i G(a_i)\pi_i - \hat{\Gamma}\int_y y f^Y(y)dy\right) \\
&+\textstyle\sum_i \mu_i \left(\int_y -u_s F_y(y \mid a_i, G(a_i))dy + \int_y u F_{yG}(y \mid a_i, G(a_i))dy + \chi_i \int_y \hat{a}(y,\mathcal{G})F_{yG}(y \mid a_i, G(a_i))dy\right)\pi_i.
\end{aligned} \tag{39}$$

The first-order condition on $C(y)$ is

$$\sum_i \beta_i u_c F_y(y \mid a_i, G_i)\pi_i + \gamma f^Y + \sum_i \mu_i \pi_i u_c F_{yG}(y \mid a_i, G_i) = 0. \tag{40}$$

The first-order condition on S_i is

$$[\ \beta_i u_{s,i} + (\gamma - \lambda)]F_y(y \mid a_i, G_i) - \mu_i[u_{ss,i}F_y(y \mid a_i, G_i)\ - u_{s,i}F_{yG}(y\ \mid a_i, G_i)] = 0. \tag{41}$$

we can transform it into

$$\lambda - \gamma = E_y\left(\beta_i u_{s,i}\right) - \mu_i \varepsilon_i^s \frac{E_y\left(u_{s,i}\right)}{G_i}, \tag{42}$$

where $\varepsilon_i^s \equiv -\frac{\partial E_y(u_{s,i})}{\partial G_i}\frac{G_i}{E_y(u_{s,i})}$.

The first-order condition on G_i is

$$\begin{aligned}
&\beta_i\pi_i \int u_i F_{yG}(y \mid a_i, G_i)dy + (\gamma - \lambda)\pi_i\left(1 + \int_y S_i F_{yG}(y \mid a_i, G_i)dy\right) \\
&-\mu_i\pi_i\left(\int_y u_s F_{yG}(y \mid a_i, G_i)dy - \int_y u F_{yGG}(y \mid a_i, G_i)dy - \chi_i \int_y \hat{a}(y, \mathcal{G})F_{yGG}(y \mid a_i, G_i)dy\right) \\
&+\int_y a_i \frac{F_{yG}(y \mid a_i, G_i)}{f^Y(y)}\pi_i\left(\sum_j \mu_j\pi_j\chi_j F_{yG}(y \mid a_j, G_j)\right)dy = 0.
\end{aligned} \tag{43}$$

When $i = L$, since $\chi_L = 0$, we can transform equation (43) into the following expression using (9):

$$\begin{aligned}
&\frac{\beta_L E_y\left(u_L\eta_L\right)}{1 + \int_y S_L F_{yG}(y \mid a_L, G_L)dy} - \frac{\mu_L}{1 + \int_y S_L F_{yG}(y \mid a_L, G_L)dy}\varepsilon_L^\eta \frac{G_L}{E_y\left(u_L\eta_L\right)} \\
&+ \chi_H \frac{\mu_H}{1 + \int_y S_L F_{yG}(y \mid a_L, G_L)dy}\frac{a_L}{\pi_L}E_y\left[\psi_G(a_L, G_L, y)\psi_G(a_H, G_H, y)\right] = -(\gamma - \lambda),
\end{aligned}$$

where $\varepsilon_L^\eta = -\frac{\partial E_y(u_L\eta_L)}{\partial G_L}\frac{G_L}{E_y(u_L\eta_L)}$, $\psi(a_L, G_L, y) = \frac{\pi_L F_y(y|a_L, G_L)}{f^Y(y)}$. Combine (42) and (38) to get

$$\begin{aligned}
\mu_L = &-\beta_L \frac{E_y\left(u_L\eta_L\right) - E_y\left(u_{s,L}\right)\left(1 + \mathcal{T}'\left(G_L\right) - E_y\left(G_L\eta_L\right)\right)}{\varepsilon_L^s \frac{E_y(u_{s,L})}{G_L}\left(1 + \mathcal{T}'\left(G_L\right) - E_y\left(G_L\eta_L\right)\right) - \varepsilon_L^\eta \frac{E_y(u_L\eta_L)}{G_L}} \\
&- \chi_H\mu_H\pi_H a_L \frac{E_y\left[\frac{\psi_G(a_L, G_L, y)}{\pi_L}\frac{\psi_G(a_H, G_H, y)}{\pi_H}\right]}{\varepsilon_L^s \frac{E_y(u_{s,L})}{G_L}\left(1 + \mathcal{T}'\left(G_L\right) - E_y\left(G_L\eta_L\right)\right) - \varepsilon_L^\eta \frac{E_y(u_L\eta_L)}{G_L}}
\end{aligned}$$

Rearrange the above expression to get equation (27). The derivation of (28) is similar.

To solve optimal marginal transfer, we first take derivatives of both sides of equation (8) on y to get

$$T'(y) = S_y(y, G_i) - \Omega \tag{44}$$

According to equation (8), $S(y, G_i)$ is separable between G_i and y. Therefore, we have $S_y(y, G_i) = S_y(y)$.

Following Boadway and Sato (2015); Jewitt (1988), define the likelihood ratio of output under a and $G(a)$ as

$$\eta(a, y) = \frac{F_{yG}(y \mid a, G(a))}{F_y(y \mid a, G(a))}.$$

Assume that $\eta_y \geq 0$ and $\eta_{yy} \leq 0$. Then we can transform the first-order condition on S_i in (41) into

$$\beta_i u_s - (\lambda - \gamma) + \mu_i(u_s \eta(a_i, y) - u_{ss}) = 0. \tag{45}$$

If utility function $u(C, S)$ is separable between S and C, by taking derivatives of both sides of equation (45) on y to get

$$\beta_i u_{ss} S_y(y) + \mu_i(\eta u_{ss} S_y(y) - u_{sss} S_y(y) + u_s \eta_y) = 0.$$

Take the expectation of the above equation on a and substitute $S_y(y)$ using (44) to get equation (26).

6.2.2 Optimal Marginal Transfers with A Continuum of Ability Types

When abilities are continuously distributed, the incentive-compatible (IC) constraint (22) indicates that the local government should not want to misreport the ability type. In other words, if local government i reports a_j and chooses $G(a_j)$, the utility $V(a_i, G(a_j))$ will be maximized if $G(a_j) = G(a_i)$. The necessary condition of the maximization problem is

$$\int_y -u_s F_y(y \mid a_i, G)\dot{G}(a_i)dy + \int_y u F_{yG}(y \mid a_i, G)\dot{G}(a_i)dy + \chi_i \int_y \hat{a}_i(y, \mathcal{G}) F_{yG}(y \mid a_i, G)\dot{G}(a_i)dy = 0, \tag{46}$$

where $\dot{G}(a_i)$ is the derivative of G on a_i.

As in Boadway and Sato (2015), the second-order condition of the maximization problem is $\dot{G}(a_i) \neq 0$, which is the sufficient condition for honest reporting. As long as $\dot{G}(a_i) \neq 0$, compared to (12), we can find that the first-order IC is just the first-order condition of the local government's optimization problem. We assume that the second-order condition holds when we solve the optimal transfer, and verify it numerically.

The central government chooses $G(a_i)$, $C(y)$ and $S(y, a_i)$ to maximize social welfare (23) subject to constraints (20), (21), (22). We construct the following Lagrange function:

$$
\begin{aligned}
&L=\int_a \beta(a)\left(\int_y u(S(y,a),C(y))F_y(y\mid a,G(a))dy\right)f^A(a)da+\\
&\lambda(\int_y \Gamma y f^Y(y)dy-\int_a G(a)f^A(a)da-\int_a\int_y S(y,a)F_y(y\mid a,G(a))dyf^A(a)da\\
&+\gamma\left(\int_y C(y)f^Y(y)dy+\int_a\int_y S(y,a)F_y(y\mid a,G(a))dyf^A(a)da+\int_a G(a)f^A(a)da-\hat{\Gamma}\int_y yf^Y(y)dy\right)\\
&+\int_a \mu(a)\left(\int_y -u_sF_y(y\mid a,G(a))dy+\int_y uF_{yG}(y\mid a,G(a))dy+\chi_i\int_y \hat{a}(y,\mathcal{G})F_{yG}(y\mid a,G(a))dy\right)f^A(a)da.
\end{aligned}
$$

The co-state variable $\mu(a)$ satisfies $\mu(\overline{a})=\mu(\underline{a})=0$. $\hat{\Gamma}$ satisfies

$$
\hat{\Gamma}\equiv\left[1-z\left(\left(1-\xi^l\right)\tau^l\left(1-\alpha\right)+\left(1-\xi^k\right)\tau^k\alpha\right)\right]
$$

The first-order condition on $S(y,a)$ indicates

$$
\beta(a)u_sF_y(y\mid a,G(a))-(\lambda-\gamma)F_y(y\mid a,G(a))+\mu(a)(u_sF_{yG}-u_{ss}F_y(y\mid a,G(a)))=0. \tag{47}
$$

The first-order condition on $G(a)$ is

$$
\begin{aligned}
&\int_y \beta(a)uF_{yG}(y\mid a,G(a))dy-(\lambda-\gamma)\left(\int_y S(y,a)F_{yG}(y\mid a,G(a))dy+1\right)\\
&+\int_y \mu(a)(-u_sF_{yG}(y\mid a,G(a))+uF_{yGG}(y\mid a,G(a))+\chi\hat{a}(y,\mathcal{G})F_{yGG}(y\mid a,G(a)))dy\,.\\
&+\chi\int_y E_a(\mu(a)F_{yG})a\frac{F_{yG}}{f_Y}dy=0
\end{aligned} \tag{48}
$$

The first-order condition on $C(y)$ is

$$
\begin{aligned}
&\int_a \beta(a)u_cF_y(y\mid a,G(a))f^A(a)da+\gamma f^Y(y)+\\
&\int_a \mu(a)(-u_{cs}F_y(y\mid a,G(a))+u_cF_{yG}(y\mid a,G(a)))f^A(a)da=0
\end{aligned} \tag{49}
$$

Integrate both sides of (49) on y to get

$$
\gamma=-\int_y\int_a \beta(a)u_cF_y(y\mid a,G(a))f^A(a)dady+\int_y\int_a \mu(a)(u_{cs}F_y(y\mid a,G(a))-u_cF_{yG}(y\mid a,G(a))f^A(a)dady.
$$

If utility function $u(C,S)$ is separable between C and S, we can transform (49) into

$$
\gamma\int_y \frac{1}{u_c(y)}f^Y(y)dy=-\int_a \beta(a)f^A(a)\int_y F_y(y\mid a,G(a))dyda-\int_a \mu(a)f^A(a)\int_y F_{yG}(y\mid a,G(a))dy. \tag{50}
$$

Since $\int_y F_y(y\mid a,G(a))dy=1$ and $\int_y F_{yG}(y\mid a,G(a))=0$, we have lemma 1:

Lemma 1. *When utility function $u(C,S)$ is separable between S and C, we have*

$$
-\int_a \beta(a)f^A(a)da=\gamma E_y\left(\frac{1}{u_c}\right).
$$

With the assumption $\int_a \beta(a) f^A(a) da = 1$*, we have:*

$$\gamma = -\frac{1}{E_y\left(\frac{1}{u_c}\right)}$$

We further transform (47) by double integrating on a and y to get

$$\int_a \int_y \beta(a) u_s F_y(y \mid a, G(a)) f^A(a) dy da + \int_a \int_y \mu(a)(u_s F_{yG} - u_{ss} F_y(y \mid a, G(a))) f^A(a) dy da = \lambda - \gamma. \tag{51}$$

To solve optimal marginal transfer, we first take derivatives of both sides of equation (8) on y to get

$$T'(y) = S_y(y, G(a)) - \Omega \tag{52}$$

According to equation (8), $S(y, G(a))$ is separable between $G(a)$ and y. Therefore, we have $S_y(y, G(a)) = S_y(y)$.

Following Boadway and Sato (2015); Jewitt (1988), define the likelihood ratio of output under a and $G(a)$ as

$$\eta(y, a, G(a)) = \frac{F_{yG}(y \mid a, G(a))}{F_y(y \mid a, G(a))}.$$

Assume that $\eta_y \geq 0$ and $\eta_{yy} \leq 0$. Then we can transform equation (47) into

$$\beta(a) u_s - (\lambda - \gamma) + \mu(a)(u_s \eta(y, a, G(a)) - u_{ss}) = 0. \tag{53}$$

If utility function $u(C, S)$ is separable between S and C, by taking derivatives of both sides of equation (53) on y to get

$$\beta(a) u_{ss} S_y(y) + \mu(a)(\eta u_{ss} S_y(y) - u_{sss} S_y(y) + u_s \eta_y) = 0.$$

Take the expectation of the above equation on a and substitute S_y using (52) to get

$$T'(y) = -E_a \left(\frac{\mu(a) u_s \eta_y}{\beta(a) u_{ss} + \mu(a)(u_{ss}\eta - u_{sss})} \right) - \Omega. \tag{54}$$

Transform it into

$$T'(y) = -E_a \left(\frac{\mu(a) \frac{u_s}{u_{ss}} \eta_y}{\beta(a) + \mu(a)(\eta - \frac{u_{sss}}{u_{ss}})} \right) - \Omega,$$

which is exactly (33).

6.2.3 Decomposition of Information Rent with Infinite Regions

We decompose the information rent in the benchmark model with two regions, as shown in Section 3.2. In the case of infinite regions, while the externality term of information rent cannot be clearly expressed as (27) due to the difficulty to solve an integral equation, we can still provide an analytical expression corresponding to information rent in Proposition 2.

Transform equation (47) to get

$$\lambda-\gamma=\int_y \beta(a)u_s F_y(y\mid a,G(a))dy+\mu(a)\int_y\left[u_s\frac{F_{yG}(y\mid a,G(a))}{F_y(y\mid a,G(a))}-u_{ss}\right]F_y(y\mid a,G(a))dy \tag{55}$$

Substitute it into equation (48) to get an equation of μ:

$$\begin{aligned}
&\int_y [\beta(a)uF_{yG}(y\mid a,G(a))-\beta(a)u_sF_y\left(\int_y S(y,a)F_{yG}(y\mid a,G(a))dy+1\right)\\
&-\mu(a)\left[u_s\frac{F_{yG}(y\mid a,G(a))}{F_y(y\mid a,G(a))}-u_{ss}\right]F_y\left(\int_y S(y,a)F_{yG}(y\mid a,G(a))dy+1\right)]dy\\
&+\int_y \mu(a)(-u_sF_{yG}(y\mid a,G(a))+uF_{yGG}(y\mid a,G(a))+\chi\hat{a}(y,\mathcal{G})F_{yGG}(y\mid a,G(a)))dy\\
&+\chi(a)a\int_y E_a\left[\mu(\tilde{a})F_{yG}(y\mid\tilde{a},G(\tilde{a}))\right]\frac{F_{yG}(y\mid a,G(a))}{f_Y(y)}dy=0
\end{aligned}$$

Transform it into

$$\mu(a)-\int_{\tilde{a}} M(a,\tilde{a})\mu(\tilde{a})d\tilde{a}=N(a), \tag{56}$$

in which

$$\begin{aligned}
N(a)&=\frac{\beta(a)}{N^d(a)}\left[-\frac{\int_y uF_{yG}(y\mid a,G(a))dy}{\int_y S(y,a)F_{yG}(y\mid a,G(a))dy+1}+\int_y u_sF_y(y\mid a,G(a))dy\right];\\
M(a,\tilde{a})&=\frac{-\chi(a)\,a}{N^d(a)}\frac{f^A(\tilde{a})\int_y F_{yG}(y\mid\tilde{a},G(\tilde{a}))\frac{F_{yG}(y\mid a,G(a))}{f^Y(y)}dy}{\int_y S(y,a)F_{yG}(y\mid a,G(a))dy+1};\\
N^d(a)&=\frac{\int_y(-u_sF_{yG}(y\mid a,G(a))+uF_{yGG}(y\mid a,G(a))+\chi\hat{a}(y,\mathcal{G})F_{yGG}(y\mid a,G(a)))dy}{\int_y S(y,a)F_{yG}(y\mid a,G(a))dy+1}\\
&\quad-\int_y\left[u_s\frac{F_{yG}(y\mid a,G(a))}{F_y(y\mid a,G(a))}-u_{ss}\right]F_y(y\mid a,G(a))dy.
\end{aligned}$$

Equation (56) is a Fredholm integral equation of the second kind.

Via using the sufficient statistics, the information rent can be disentangled into different parts consistent with those in (27) and (28):

$$\mu(a) = \beta(a)\left[\underbrace{\left(1+\mathcal{T}\left(G_i\right)-E_y\left(G_i\eta_i\right)\right)E_y\left(u_s\right)}_{\text{Budget-based Social Welfare Multiplier}}-\underbrace{E_y\left[u\eta(y \mid a,G\left(a\right))\right]}_{\text{Risk-based Social Welfare Multiplier}}\right]\underbrace{\widetilde{\varepsilon}}_{\text{Behavioral Elasticity}}$$
$$+\underbrace{\int_{\tilde{a}} M\left(a,\tilde{a}\right)\mu(\tilde{a})d\tilde{a}}_{\text{Correction of Interregional Tournaments}} \tag{57}$$

where the behavioral elasticity $\widetilde{\epsilon}$ can be further expressed as:

$$\widetilde{\varepsilon} = \left(\underbrace{\varepsilon^s\frac{E_y\left(u_s\right)}{G}\left(1+\mathcal{T}'\left(G\right)-E_y\left(G\eta\right)\right)}_{\text{Price Channel}}\underbrace{-\varepsilon^\eta\frac{E_y\left(u\eta\right)}{G}}_{\text{Distribution Channel}}\underbrace{+\chi\widetilde{\Xi}(a,G)}_{\text{Tournament Channel}}\right)^{-1} \tag{58}$$

The elasticities $\varepsilon^s = -\frac{\partial E_y(u_s)}{\partial G}\frac{G}{E_y(u_s)}$, $\varepsilon^\eta = -\frac{\partial E_y(u\eta)}{\partial G}\frac{G}{E_y(u\eta)}$ and $\widetilde{\Xi}(a,G) = \chi(a)\int_y \hat{a}(y)F_{yGG}(y \mid a,G)dy$, the former two of which exactly correspond to the behavioral elasticity in (30). The externality term $\widetilde{\Xi}$ is different from the term Ξ in (27) because the item $\chi_j\int_y a\frac{F^2_{yG}(y|a,G)}{f^Y(y)}\pi dy$ is included in $M(a,\tilde{a})$.

6.3 Supplementary Theoretical Results

6.3.1 The Optimization of A Representative Firm

The first-order conditions on L_i and K_i are

$$\left(1-\alpha\right)A_iK_i^\alpha L_i^{-\alpha}G_i^g = \Phi_i;$$
$$\alpha A_iK_i^{\alpha-1}L_i^{1-\alpha}G_i^g = R.$$

In the equilibrium, $L_i = 1$. Therefore, we have:

$$\Phi_i = \left(1-\alpha\right)A_iK_i^\alpha G_i^g$$

and

$$K_i = \left(\frac{\alpha A_i}{R}\right)^{1/(1-\alpha)}G_i^g.$$

Put the two expressions into (1) to get (4).

6.3.2 Decomposition of information rent under extremely low risk

Corollary 2. *When ε is close to 0, we have $cov_y(u_L,\eta_L)$, $cov_y(u_H,\eta_H)$ and Ψ all close to 0.*

Corollary 2 indicates that when unobservable economic shock is extremely small, the interregional insurance and interregional economic competition have little influence on information rents to all regions. As a result, information rents implied in the optimal transfer only need to consider the fiscal gaps of each type of local government. Intuitively, without interregional economic fluctuation, the central government faces only the adverse selection problem due to unobservable abilities. Under the optimal transfer, all local governments are incentive-compatible. Therefore, the central government can directly locate a governor's ability based on local output, and externalities caused by interregional competitions no longer exist.

Proof: When ε is close to 0, $F_y\left(y \mid a_i, G\left(a_i\right)\right)$ is close to a Dirac function. This means

$$F(y \mid a_H, G_H) = \begin{cases} 1 & if \ y \geq y_H; \\ 0 & if \ y < y_H. \end{cases}$$

We can transform $E_y(u_H \eta_H)$ into

$$\begin{aligned} E_y(u_H \eta_H) = & \int_y u_s F_{yG}(y \mid a_H, G_H) dy = \int_y u_s dF_G(y \mid a_H, G_H) \\ = & F_G(y \mid a_H, G_H) u_s|_{y=\infty} - F_G(y \mid a_H, G_H) u_s|_{y=0} - \int_y F_G(y \mid a_H, G_H) du_s. \end{aligned}$$

From the expression of $E_y(u_H \eta_H)$, we obtain $F_G(y \mid a_H, G_H) u_s|_{y=\infty} = F_G(y \mid a_H, G_H) u_s|_{y=0} = 0$. Therefore, $E_y(u_H \eta_H)$ is close to 0. Similarly, $E_y(\eta_H)$ is close to 0. As a result, $cov(u_H, \eta_H)$ is close to 0. The proof that $cov(u_L, \eta_L)$ is close to 0 is the same and therefore omitted.

Since

$$\psi = \psi\left(a_i, G_i, y\right) = \frac{F_y\left(y \mid a_i, G\left(a_i\right)\right) \pi_i}{\sum_j F_y\left(y \mid a_j, G\left(a_j\right)\right) \pi_j}, \quad i, j = H, L$$

we have $\psi\left(a_i, G_i, y_i\right)$ close to 1 and $\psi\left(a_i, G_i, y_j\right)$ close to 0 $(i \neq j)$. Taking derivative of ψ on G_i, we have

$$\begin{aligned} \frac{\partial \psi\left(a_i, G_i, y\right)}{\partial G_i} = & \frac{F_{yG}\left(y \mid a_i, G\left(a_i\right)\right) \pi_i}{\sum_j F_y\left(y \mid a_j, G\left(a_j\right)\right) \pi_j} - \frac{F_y\left(y \mid a_i, G\left(a_i\right)\right) F_{yG}\left(y \mid a_i, G\left(a_i\right)\right)}{\left(\sum_j F_y\left(y \mid a_j, G\left(a_j\right)\right) \pi_j\right)^2} \\ = & \frac{F_{yG}\left(y \mid a_i, G\left(a_i\right)\right) \pi_i}{\sum_j F_y\left(y \mid a_j, G\left(a_j\right)\right) \pi_j} - \frac{F_y\left(y \mid a_i, G\left(a_i\right)\right)}{\sum_j F_y\left(y \mid a_j, G\left(a_j\right)\right) \pi_j} \frac{F_{yG}\left(y \mid a_i, G\left(a_i\right)\right)}{\sum_j F_y\left(y \mid a_j, G\left(a_j\right)\right) \pi_j} \\ = & \frac{F_{yG}\left(y \mid a_i, G\left(a_i\right)\right) \pi_i}{\sum_j F_y\left(y \mid a_j, G\left(a_j\right)\right) \pi_j} - \psi\left(a_i, G_i, y\right) \frac{F_{yG}\left(y \mid a_i, G\left(a_i\right)\right)}{\sum_j F_y\left(y \mid a_j, G\left(a_j\right)\right) \pi_j}. \end{aligned}$$

As $\psi\left(a_i, G_i, y_i\right)$ is close to 1, we get $\psi_G\left(a_i, G_i, y_i\right)$ is close to 0. For $i \neq j$, we have $F_y\left(y_j \mid a_i, G\left(a_i\right)\right) = 0$. As a result, $F_{yG}\left(y_j \mid a_i, G\left(a_i\right)\right) = 0$. Thus, $\psi_G\left(a_i, G_i, y_j\right)$ is close to 0. Combine these results with the expression of Ψ in (29), we conclude that Ψ is close to 0.

6.3.3 Optimal transfer under full information

In this part, we solve the optimal transfer when the central government can observe the abilities of local governors and abilities are continuously distributed. In this case, the optimal transfer $T(y, a)$ is a function of both output and ability. The local government's budget constraint then becomes

$$S(y, a) = T(y, a) + \Omega y - G(a) \tag{59}$$

The central government's optimization problem is to maximize social welfare (23) under constraints (20) and (21). Its choice variables are $G(a)$, $C(y)$ and $S(y, a)$.

We construct the following Lagrange function

$$\begin{aligned} &L = \int_a \beta(a) \left(\int_y u(S(y,a), C(y)) F_y(y \mid a, G(a)) dy \right) f^A(a) da + \\ &\lambda(\int_y \Gamma y f^Y(y) dy - \int_a G(a) f^A(a) da - \int_a \int_y S(y,a) F_y(y \mid a, G(a)) dy f^A(a) da \\ &+\gamma \left(\int_y C(y) f^Y(y) dy + \int_a \int_y S(y,a) F_y(y \mid a, G(a)) dy f^A(a) da + \int_a G(a) f^A(a) da - \hat{\Gamma} \int_y y f^Y(y) dy \right). \end{aligned}$$

As in proposition 1, assume that the utility function u is additive with respect to the private consumption C and non-productive public spending S, and the utility function of S takes the form of CARA.

By solving the first order conditions of the optimization problem, we have

$$\beta(a) u_s F_y(y \mid a, G(a)) - (\lambda - \gamma) F_y(y \mid a, G(a)) = 0. \tag{60}$$

This equation indicates that $\beta(a) u_s = \lambda - \gamma$ and S is independent of y, which further leads to:

$$\frac{\partial S(y,a)}{\partial y} = 0; \quad \frac{\partial S(y,a)}{\partial a} = \frac{1}{r} \frac{\beta'(a)}{\beta(a)}; \quad \frac{\partial T(y,a)}{\partial y} = -\Omega; \quad \frac{\partial T(y,a)}{\partial a} = \frac{\partial S(y,a)}{\partial a} + G'(a).$$

We can also take the derivate of the first-order condition of $G(a)$ on a to get

$$G'(a) = -\frac{\partial S(y,a)}{\partial a} \frac{\int_y u_s F_{yG}(y \mid a, G(a)) dy - u_s - u_{ss}\,(S(a)+1)}{\int_y u F_{yGG}(y \mid a, G(a)) dy} - \frac{\int_y u F_{yGa}(y \mid a, G(a)) dy}{\int_y u F_{yGG}(y \mid a, G(a)) dy}$$

Therefore, when $\beta(a) = 1$, we have $\frac{\partial S(y,a)}{\partial a} = 0$ and

$$\frac{\partial T(y,a)}{\partial a} = -\frac{\int_y u F_{yGa}(y \mid a, G(a)) dy}{\int_y u F_{yGG}(y \mid a, G(a)) dy}.$$

6.4 Numerical Analysis

6.4.1 Calibration Method

When local governance capacity and productivity shocks are normally distributed and independent of each other, the distribution function needed for simulation can be expressed as:

$$f^E(\varepsilon) = \frac{1}{\sigma_\varepsilon\sqrt{2\pi}} \exp\left(-\frac{(\varepsilon-\mu_\varepsilon)^2}{2\sigma_\varepsilon^2}\right); F^E(\varepsilon) = \frac{1}{\sigma_\varepsilon\sqrt{2\pi}} \int_{-\infty}^{\varepsilon} \exp\left(-\frac{(t-\mu_\varepsilon)^2}{2\sigma_\varepsilon^2}\right) dt$$

$$f^A(a) = \frac{1}{\sigma_a\sqrt{2\pi}} \frac{1}{a} \exp\left(-\frac{(\log a-\mu_a)^2}{2\sigma_a^2}\right)$$

$$f^Y(y) = (1-\alpha)\frac{1}{y}\int_A f^E\left((1-\alpha)\log y-(1-\alpha)\log G(a)-\alpha\log\left(\frac{\alpha}{R}\right)-\Lambda(a)\right) f^A(a)\, da$$

In simulation we have $\Lambda(a) = a^{0.5}$. The calibration is performed as follows.

1. Discretization: Take the grid points on the distributions of a and y separately.
2. Fit the real transfer function. By fitting the equation (35) with the transfer data of the central government to the county-level local governments in 2019 and the local per capita GDP data, the values of ϕ_1, ϕ_2, y_0 are obtained.
3. Set the parameters used in the initial calculation. Set the initial value of $\chi, \mu_\varepsilon, \sigma_\varepsilon$ and the mapping between the initial a and $G(a)$. According to the distribution of local governments' investment public spending per capita GDP, calculate the mean and variance of y and G, and solve μ_a, σ_a according to the following relations:

$$var(\log y) - var(\log G) = \left(\frac{1}{1-\alpha}\right)^2 \left[\sigma_\varepsilon^2 + var(\mathit{\Lambda}(a))\right] + \frac{2}{1-\alpha} cov(\log y, \log G); \tag{61}$$

$$(E\log y - E[\log G])(1-\alpha) = [E(\mathit{\Lambda}(a)) + \mu_\varepsilon] + \alpha\log\left(\frac{\alpha}{R}\right). \tag{62}$$

4. Inner iteration: Given the realistic transfer system, parameters $\{\chi, \mu_\varepsilon, \mu_a, \sigma_\varepsilon, \sigma_a\}$ and function $G(a)$, solve a_i for each G_i to update the function $G(a)$ using the first-order condition (12) of local governments. Calculate the error between two $G(a)$ functions. Update μ_a, σ_a based on solutions of a and $\mu_\varepsilon, \sigma_\varepsilon$ according to (61) and (62).
5. Repeat the inner iteration process until the function $G(a)$ converges. When the initial guess χ is obviously biased from the true value, and the distribution of the a obtained is not normal, then χ needs to be updated.
6. Update χ. Using kernel function method to estimate the density function of a. Take 100 grid points on the distribution of a, we get $a_j, j = 1, 2, ..., 100$ and the corresponding probability density $\hat{f}(a_j)$. Interpolate $G(a)$ to get $G(a_j)$. We can obtain another density function $\tilde{f}(a)$ using the density function formula of the

normal distribution and the mean and variance of a. Correct a obtained in Step 5 using the following expression:

$$\tilde{a}_j = \tilde{f}^{-1}\left(\hat{f}\left(a_j\right)\right)$$

Solve χ_j on each combination of $\tilde{a}_j$ and $G(a_j)$ using condition (12). Update χ by interpolating the realistic G over $\chi(G)$. Calculate the difference between the new χ and the old χ.

7. Repeat Steps 3-6 until function $\chi(a)$ converges.

6.4.2 Simulation algorithm

1. Set parameters. Uniformly select 100 grid points on the distribution of y and a, where a_1 corresponds to the minimum value of the governance capability level obtained from the calibration part, and a_{100} corresponds to the maximum value of the governance capability level obtained from the calibration part. Interpolate function $\chi(a)$ on a_1 to a_{100} to get χ_i. At each grid point of y, specify the marginal transfer and total transfer levels for the initial period of the iteration.
2. Solve optimal allocations under a given transfer plan. Based on equation (5) and the results of the producer's optimization problem, the consumption at different grid points of y can be calculated as:

$$C_i = \left[\left(1-\tau^l\right)(1-\alpha) + \left(1-\tau^k\right)\alpha\right] Y_i$$

For each a_i, solve G_i under the given transfer plan using first-order conditions of the local government's optimization problem:

$$\int_y -u_s F_y^l(y \mid a, G) dy + \int_y u F_{yG}^l(y \mid a, G) dy + \chi_i \int_y \hat{a}(y) F_{yG}^l(y \mid a, G) dy = 0$$

According to the solution of G_i, update probability density of $F(y|a_i, G_i)$ and $f^Y(y)$. At each grid point of $a \times y$, calculate the consumption of local government $C_i(y)$ and $S_i(y, a)$ after different output shocks are realized.

Based on (24), calculate the local government's ability inferred by the central government at each grid of income as follows:

$$\hat{a}(y) = \frac{1}{f^Y(y)} \int_{\underline{a}}^{\overline{a}} a F_y^l(y \mid a, G(a)) f^A(a) da \tag{63}$$

3. Solve Lagrange multipliers for the central government's optimization problem. The multipliers λ and γ can be solved using (55) and Lemma 1, while μ is shown in (56), which is a Fredholm equation of the second kind. Following Sachs et al. (2020), discrete the equation into:

$$\mu(a_j) - \sum_{\tilde{a}=a_1}^{a_N} M\left(a_j, \tilde{a}\right) \mu(\tilde{a}) \Delta a = N\left(a_j\right); a_j \in \{a_1, a_2, ...a_N\}.$$

Define vectors $\boldsymbol{\mu} = [\mu(a_1), \mu(a_2), \mu(a_3), ...\mu(a_N)]$; $\boldsymbol{N} = [N(a_1), N(a_2), N(a_3), ...N(a_N)]$. Define the following matrix

$$\boldsymbol{M} = \begin{bmatrix} M(a_1,a_1)\Delta a & M(a_1,a_2)\Delta a & ... & M(a_1,a_N)\Delta a \\ M(a_2,a_1)\Delta a & M(a_2,a_2)\Delta a & ... & M(a_2,a_N)\Delta a \\ ... & ... & ... & ... \\ M(a_N,a_1)\Delta a & M(a_N,a_2)\Delta a & ... & M(a_N,a_N)\Delta a \end{bmatrix}$$

Then we have

$$(\boldsymbol{I} - \boldsymbol{M})\boldsymbol{\mu} = \boldsymbol{N}$$

Use $\boldsymbol{\mu} = (\boldsymbol{I} - \boldsymbol{M})^{-1}\boldsymbol{N}$ to get $\boldsymbol{\mu}$.

4. Update the optimal transfer plan. Solve $T'(y)$ using the optimal marginal transfer equation (33). Then we can obtain

$$T(y) - T(\underline{y}) = \int_{\underline{y}}^{y} T'(\tilde{y})\, d\tilde{y}$$

Use the budget constraint of the central government to update $T(\underline{y})$:

$$\begin{aligned} T(\underline{y}) =&(1-z)\int_y \left(\left(1-\xi^l\right)\tau^l(1-\alpha) + \left(1-\xi^k\right)\tau^k\alpha\right) y f^Y(y)dy - \int_y \left[\int_{\underline{y}}^{y} T'(\tilde{y})\, d\tilde{y}\right] f^Y(y)dy \\ =&(1-z)(1-\alpha)\int_y \left(\left(1-\xi^l\right)\tau^l(1-\alpha) + \left(1-\xi^k\right)\tau^k\alpha\right)\times \\ &\left[\int_A f^E\left((1-\alpha)\log y - (1-\alpha)\log G(a) - \alpha\log\left(\frac{\alpha}{R}\right) - a\right) f^A(a)\, da\right] dy \\ &- \int_y \left[\int_{\underline{y}}^{y} T'(\tilde{y})\, d\tilde{y}\right] f^Y(y)dy \end{aligned}$$

5. Using the updated transfer and marginal transfer levels, repeat steps 2-4 until the transfer levels used in the neighboring two calculations are nearly the same.
6. Changes the initial parameter of the simulation. To compare the effects of tax sharing and career concern, set $\Omega = 0.1425$, $\Omega = 0.0855$, and $\chi = 0.36$, respectively, and repeat steps 1-5.

Supplementary information.

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