On State Capital Income Tax

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Tax Competition with Population Growth

Abstract

This paper analyzes the pattern of strategic interaction on capital tax rates among states in the U.S. This paper is the first to apply MLE estimation of the SAR panel data model with fixed-effects to study tax competition behavior. Through a joint investigation into both tax competition behavior and the capital allocation decision, I demonstrate the existence of capital tax competition among states in the South and West, but competition is less significant in the Midwest and Northeast. I continue to apply a high-order SAR panel data estimation with fixed-effects to study the impact of population growth on tax competition, and the estimation results suggest that faster population growth significantly relates to stronger reaction to changes in neighbors' tax policy. I also apply two weighting schemes of neighbors to validate the findings. A two-period structural model with a saving decision is developed to explain this result. The model features a capital dilution effect which is also tested empirically in this paper.

1 Introduction

A long line of literature has been focusing on interaction among governments. One source of interaction is the mobile capital moving across jurisdictions, which leads to the series of theoretical literature on tax competition. Bucovetsky (1991) is among the pioneering literature which presents that strategic interaction leads to underprovision of public goods as each jurisdiction sets a tax rate so low to preserve the tax base. Kanbur and Keen (1993), together with Bucovetsky (1991), provide models with unequal population size and conclude that the equilibrium tax rates are higher in more populated areas. Pi and Zhou (2013) consider all-purpose public goods, which increase private firms' productivity through provision of infrastructure, and demonstrate that tax competition does not necessarily lead to inefficient outcomes.

The main strand of empirical literature tests the presence of strategic interaction among governments, through estimating reaction functions, and tax competition framework represents the best known example of the resource-flow models. Brueckner (2003) provides an overview of related empirical studies, which summarizes papers estimating tax reaction functions in Boston metropolitan areas (Brueckner and Saavedra, 2001), in Canada (Brett and Pinkse, 2000; Hayashi and Boadway, 2001) and etc. Almost all the empirical results confirm a positive presence of strategic interaction, implying that the decision variables are "strategic complements".

In the U.S., competition over capital can also be a potential issue among states. In 2005, Intel company, originated in California, decided to establish their multibillion chip-making factory in Arizona, due to the more favorable corporate income tax environment there. In 2015, General Electric warned their 42-year-old home state Conneticut of their rising corporate income tax rate, before actually leaving for Boston. Besides all these facts of firms making business decisions based on capital income tax system, there also seems to exist capital tax policy interaction among some states. New Mexico has started a schedule of cutting state corporate income tax rate from 6.9 in 2016 to 6.6 in 2017 and to a target of 5.9 in 2018; its neighbor Arizona, meanwhile, has reduced its corporate income tax rate from 6.0 in 2015 to 5.5 in 2016, and has planned to keep this falling trend to 2017 and 2018.(Walczak, Drenkard, and Henchman, 2016)

Utilizing a panel data of average capital tax rates from 1958 to 2007 at the state-level in the US, this paper verifies the existence of capital tax competition. Besides OLS panel regression, I apply spatial autoregressive (SAR) panel estimation proposed by Elhorst (2003) to avoid the potential endogeneity problem of regressors. The results of SAR estimation are qualitatively consistent with those of OLS estimation.

Moreover, this paper is the first to uncover the difference in competition patterns among states in the South and West, with that in the Midwest and Northeast. Furthermore, it is also the first to explore the underlying reason for this difference, utilizing high-order SAR panel estimation with fixed-effects. Controlling for macroeconomic and political environment features of each state, the effect of population growth rate on the reaction coefficient is positive and significant. Faster population growth induces stronger tax competition behavior.

To support the argument that tax competition explains the interaction of tax rates, the relationship between tax base and its own and neighbors' tax rates is estimated. As expected, capital is negatively related to own tax rate and positively related to neighbors' tax rates, which further confirms the view of states having a tax cut to fight over the tax base.

In contrast to the result in Chirinko and Wilson (2013), the response coefficients obtained in this paper are positive and siginificant in the South and West. They estimate the tax competition pattern among states in the U.S. using data on investment tax credits (ITC) and corporate income tax (CIT), but fail to show the existence of tax competition empirically. Compared to their study, this paper applies a new data series of average capital tax rates with a longer timespan and also deals with specific features in different areas of the U.S.

The theoretical literature, however, has been silent regarding the slope of the reaction function. This paper studies the behavior of tax competition and its relationship with population growth.

Keen and Kotsogiannis (2002) explore vertical and horizontal tax externalities with a saving model. Population growth is introduced in this paper based on their framework, to study the interaction between population growth and tax competition pattern.

Many researchers are concerned that a faster population growth brings cost to a society by reducing natural resources, physical and human capital per worker, which is widely known as "dilution effect". Apart from many theoretical support (Samuelson, 1975; Deardoff, 1976; Galor and Weil, 1996), Mankiw, Romer and Weil (1992) examine a sample that includes almost all countries[1] between 1960-1985 and provide empirical evidence that population growth rate has important effect on per capita income quantitatively. A higher population growth rate spreads capital and other resources more thinly such that capital per cap is lower, while a lower rate increases capital intensity in the economy.

In this paper, faster population growth leads to a larger gap between the number of people who save and people who share the increased capital, and thus capital is more diluted in the second period. Any tax cut attracts less inflow of capital per worker in the area with faster population growth. An additional effect is that given any tax cut from neighboring

[1] Central-planned countries are excluded.

state, the effect of capital outflow is more severe since the compensated capital from saving is more spread out in the second period. Hence, states compete in a more fierce manner due to the dilution effect.

Eakin (1994) investigates the role of public infrastructure on private firms' production at state-level in the US, and shows that public good has little effect on private firms' production possibilities, while private capital has effect on its productivity. This empirical evidence motivates the form of production function applied in the theoretical model, which is different from Pi and Zhou (2013).

There is no ambiguity regarding the effect of population growth rate on the degree of inefficiency. In particular, tax competition is more damaging when competing states have higher population growth rates. This paper analyzes the welfare implications of tax competition from another point of view, based on Keen and Kotsogiannis (2004).

The structure of this paper is as follows: Section 2 introduces the dataset, and Section 3 provides empirical findings. Section 4 presents the structural model with population growth. Lastly, Section 5 concludes.

2 U.S. State-Level Panel Data

The estimation of tax competition is based on the estimated coefficients of capital-tax reaction function in different areas of the U.S. The U.S. state-level panel data is for the period 1958-2007. I estimate the results for the four areas of the U.S.: Midwest, South, West and Northeast[2]. The analysis is on how the capital tax rate of one state is determined by the capital tax rates of its neighbors within the same area. Each area has its own specific growth rate of population for the past half century, and the study focuses on the relationship between the degree of capital tax competition and how fast population grows. Details about data sources and variable definitions are presented in Appendix II.

A. Capital tax rate

The officially available data on capital taxation includes marginal capital gains tax rates, brackets and so on. These information have been used to calculate effective capital tax rates. In most theoretical models, return from capital investment is taxed proportionally and thus the tax rate is simplified as an average tax rate. Moreover, average capital tax rates can combine the effects of different categories of capital taxation into one index, which allows for the fact that states might use different tax instruments to attract business. However, insufficient empirical work has been done to obtain average capital tax rates at the state-level in the U.S. Thus, I obtained my own series of average capital tax rates for each state.

B. Control Variables

Capital is not only taxed at the state-level, but also at the federal-level in the U.S. Thus, the first control variable is the federal effective capital gains tax rate at each year, which is

[2] A list of states in this four areas is included is in Appendix I.

common to all the states. The influence from capital tax rate at the federal-level on the tax rate at the state-level can be examined.

I also account for macro-economic condition and political environment.

Personal income at the state-level is applied to represent macro-economic condition in each state for each year.

Political environment is hardly observed, and electoral outcome serves as a good proxy. I apply the series of data on legislature's party of each state. I measure three alternatives: the fraction of State House that is Democrat, the fraction of State Senate that is Democrat and a dummy variable representing whether the majority of State House and Senate are Democrat.

C. Weighting Scheme

There are many possible schemes for econometricians to describe a neighbor and assign the weights. The notion of close proximity can refer to closedness of geopraphic location or similarity of industrial environment.

Pinkse, Slade and Brett (2002) investigate the nature of competition with measures including nearest neighbors geographically, sharing markets with common boundaries and located a certain Euclidean distance apart. They find that the competition is highly localized and rivalry decays abruptly with geographic distance.

Moreover, physical capital is imperfectly mobile across states, with cost of moving and adjusting to new social, cultural and political environment. Thus, it is natural to start with a geographic-based weighting scheme, following many empirical literature including Brueckner and Saavedra (2001), Chirinko and Wilson (2013), Buettner (2003), Brett and Pinkse (2000).

The weighting matrix W can be time-invariant or time-variant. I first consider the case with time-invariant W, such that $W = I_T \otimes W_n$.

The first scheme assigns equal weights to all contiguous states[3], so $w_{ij} = 1$ if states i and j share the same border geographically.

Equally weighted scheme, however, is insufficient to discriminate among all the contiguous neighbors in the same area. The second scheme is to combine both geographic and economic distance, where w_{ij} is adjusted by population size for each contiguous state, assuming a bigger influence from a more populous neighbor. I take the time-average population size for each state first, so W is time-invariant.

Table 1: Weighting Schemes of SAR Panel Estimation

Scheme 1	Contiguous neighbors only, equally weighted.
Scheme 2	Contiguous neighbors only, weighted by time-average population size.

D. Population growth rates

[3] To focus on the pattern of tax competition in each area, I confine the pool of neighbors as all the states in that area only.

This paper examines how population growth rate influences the degree of capital tax competition in each area.

The major four areas in the U.S. have different population growth rates. Population has been growing much faster in the South and West, compared to Midwest and Northeast. I obtain the series of state population data from 1958 to 2007 and calculate the time-average population growth rates for these 50 years for each state. The time-average growth rates are summarized in Appendix II.

The time-average population data is also used to assign weights in the spatial estimation, as above in section C.

And the series of historic population data for each state and each year is also used in the capital response regression.

3 Empirical Findings

This paper analyzes the patterns of capital tax competition among states in the South, Midwest, West and Northeast. Southern states such as Alabama and Georgia are known to have higher population growth rates, compared to Midwestern states like Michigan. The main goal in this section is to first examine the existence of capital tax competition in these four areas of the U.S., and then to test whether the tax competition is stronger among states with faster population growth, through estimating the tax reaction function.

The estimation starts with OLS estimation and proceeds to spatial autoregressive (SAR) panel estimation.

3.1 Empirics on tax competition pattern

The basic estimated reaction equation takes the form:

$$OTR_{st} = \beta \cdot TN_{st} + \gamma \cdot TF_t + \mathbf{X}_{st} \cdot \tau + u_s + \epsilon_{st} \tag{1}$$

where OTR_{st} is the own capital tax rate of state s at year t, TN_{st} is the average neighbors' capital tax rates of state s at year t, and thus β captures the degree of capital tax competition. TF_t is the federal capital tax rate at year t. $\mathbf{X}_{st}$ is a row vector of exogenous explanatory variables, with macroeconomic and political environments included in this paper. PI_{st} is personal income level as an explanatory variable to account for the macroeconomic characteristic in state s at time t. Policy makers' preferences are largely involved in the tax setting process. To account for political environment, I add legislature's party as another explanatory variable. D_H_{st} and D_S_{st} are the fraction of state house that is democrat, the fraction of state senate that is democrat respectively, which represent the political environment in state s at time t. d_{st} captures whether democrat is majority in state house and state senate. Details of variables are presented in Appendix II. As unobservable individual features of each state, including historical or institutional factors, may influence policy on capital taxation, u_s captures the fixed-effects. ϵ_{st} is a random error term.

All variables are summarized in Table 2.

Table 2: Abbreviations of variables

OTR_{st}	own capital tax rate of state s at year t
TN_{st}	average neighbors' capital tax rates of state s at year t
TF_t	federal capital tax rate at year t
g_s	time-average population growth rate of state s
g_{st}	population growth rate of state s at year t
X_{st}	exogeneous features of state s at year t
PI_{st}	personal income of state s at year t
D_H_{st}	fraction of state house that is democrat of state s at year t
D_S_{st}	fraction of state senate that is democrat of state s at year t
k_{st}	capital per cap of state s at time t
d_{st}	whether democrat is majority in state house and senate of state s at time t

Figure 1 and 2 contrast the pattern of capital tax rates between Alabama and Michigan with their neighbors' average[4]. Tax rates in Alabama and its neighbors closely follow each other; while in Michigan, no such pattern exists.

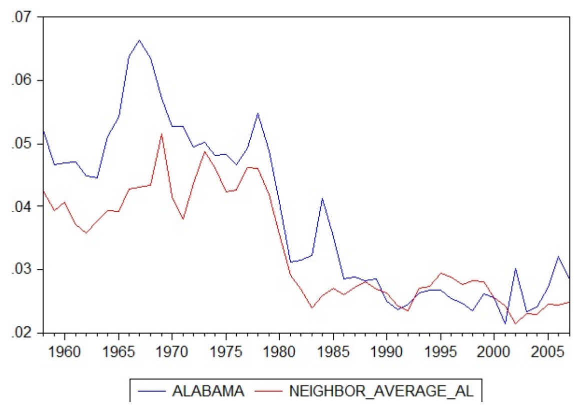

Figure 1: Capital tax rates of Alabama and its neighbors' average.

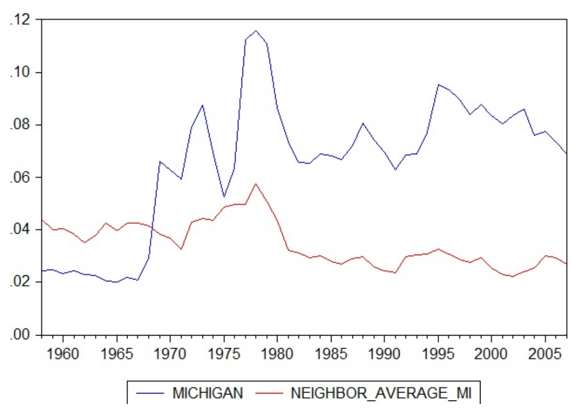

Figure 2: Capital tax rates of Michigan and its neighbors' average.

[4]Scheme 1 of defining neighbors is applied in this estimation, with every contiguous neighbor being equally weighted.

Moreover, Table 3 displays a preliminary comparison between Alabama and Michigan, where own state tax rates respond much stronger to neighbors' tax change in Alabama than that in Michigan.

Table 3: Tax competition regressions.
Dependent variable: OwnTaxRate

Explanatory Variables	Alabama	Michigan
TaxNeighbor	1.184^{***}	0.157
	(0.090)	(0.424)
TaxFed	-0.095^{***}	0.371^{***}
	(0.022)	(0.104)
Constant	0.016^{**}	-0.005
	(0.006)	(0.028)

Note: These are least squares estimates of the parameters in Eq. (1).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

To investigate tax competition patterns in the South, Midwest, West and Northeast, I run individual panel regressions with fixed effect[5] for each of these four areas.

Specifications with different explanatory variables are estimated[6].

Results of both neighboring schemes show that capital taxes compete in a stronger and more significant manner in the South and West, compared to that in the Midwest and Northeast. Moreover, adjusting the weights by population size magnifies these differences.

In addition, state capital tax rates respond to federal capital tax rates negatively yet insignificantly in most specifications.

To avoid the endogeneity problem of the regressors, SAR estimation is adopted in next subsection.

Alternatively, Chirinko and Wilson (2013) suggest estimating with political preference as an instrumental variable can take care of the endogeneity problem.

3.2 Spatial Autoregressive Panel Estimation

To avoid simultaneity problem of regressors from OLS estimation, I use a spatial autoregressive (SAR) panel model to estimate the effect of neighbors' tax rates on own state tax rates.

$$Y = \lambda WY + X\beta + l_T \otimes u_n + \epsilon \tag{2}$$

where Y is an $nT \times 1$ vector of own state tax rates, W is an $nT \times nT$ weighting matrix, X is an $nT \times k$ vector of exogenous variables, β is a $k \times 1$ vector of parameters, u_n is an $n \times 1$ vector of fixed-effect errors, and ϵ is an $nT \times 1$ vector of random errors. n is the

[5] Hausman test suggests that fixed-effect estimator is preferred.

[6] Results of OLS estimation are robust to those of SAR panel estimation and thus omitted in this paper.

number of states in one area, T is the number of years and k is the number of exogeneous state-dependent exogeneous variables included. And λ captures the degree of capital tax competition.

For South, Midwest, West and Northeast, I run the SAR Panel estimation with spatial fixed effect for each specification and each neighboring scheme, with the results summarized below.

Table 4: Tax competition regressions, SAR Panel with spatial fixed effect

	Scheme 1			
	South	South	South	South
$WTaxrate$	0.314***	0.235***	0.280***	0.313***
	(0.037)	(0.039)	(0.037)	(0.037)
TaxFed	-0.050***	-0.033***	-0.044***	-0.052***
	(0.013)	(0.012)	(0.012)	(0.013)
Personal Income	-3.1e-08***	2.2e-09	1.8e-08***	-2.8e-08***
	(4.5e-09)	(6.1e-09)	(6.2e-09)	(5.8e-09)
Democrat_House		0.036***		
		(0.004)		
Democrat_Senate			0.045***	
			(0.004)	
Political Dummy				0.001
				(0.001)

Note: These are SAR Panel estimates with fixed-effect of the parameters in Eq. (2).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Table 5: Tax competition regressions, SAR Panel with spatial fixed effect

	Scheme 2			
	South	South	South	South
$WTaxrate$	0.348***	0.297***	0.320***	0.350***
	(0.034)	(0.035)	(0.034)	(0.034)
TaxFed	-0.045***	-0.027**	-0.039***	-0.047***
	(0.013)	(0.012)	(0.012)	(0.013)
Personal Income	-2.6e-08***	6.0e-09	2.2e-08***	-2.4e-08***
	(4.5e-09)	(6.0e-09)	(6.1e-09)	(5.7e-09)
Democrat_House		0.034***		
		(0.004)		
Democrat_Senate			0.046***	
			(0.004)	
Political Dummy				0.001
				(0.001)

Note: These are SAR Panel estimates with fixed-effect of the parameters in Eq. (2).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Table 6: Tax competition regressions, SAR Panel with spatial fixed effect

	Scheme 1			
	Midwest	Midwest	Midwest	Midwest
WTaxrate	0.082	0.049	0.071	0.056
	(0.051)	(0.051)	(0.050)	(0.050)
TaxFed	-0.012	-0.015	-0.023	-0.021
	(0.017)	(0.016)	(0.017)	(0.016)
Personal Income	1.3e-08	2.0e-08***	2.1e-08***	2.0e-08***
	(7.7e-09)	(7.6e-09)	(7.7e-09)	(7.6e-09)
Democrat_House		0.024***		
		(0.006)		
Democrat_Senate			0.019***	
			(0.006)	
Political Dummy				0.004***
				(8.4e-04)
Missing_Political		0.032***	0.030***	0.025***
		(0.005)	(0.005)	(0.004)

Note: These are SAR Panel estimates with fixed-effect of the parameters in Eq. (2).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Table 7: Tax competition regressions, SAR Panel with spatial fixed effect

	Scheme 2			
	Midwest	Midwest	Midwest	Midwest
WTaxrate	0.109**	0.047	0.070	0.052
	(0.048)	(0.048)	(0.048)	(0.047)
TaxFed	-0.012	-0.015	-0.023	-0.021
	(0.017)	(0.016)	(0.017)	(0.016)
Personal Income	1.2e-8	2.0e-08***	2.0e-08***	2.0e-08
	(7.7e-09)	(7.6e-09)	(7.7e-09)	(7.6e-09)
Democrat_House		0.023***		
		(0.006)		
Democrat_Senate			0.019***	
			(0.006)	
Political Dummy				0.004***
				(8.4e-04)
Missing_Political		0.031***	0.029***	0.024***
		(0.005)	(0.005)	(0.004)

Note: These are SAR Panel estimates with fixed-effect of the parameters in Eq. (2).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Table 8: Tax competition regressions, SAR Panel with spatial fixed effect

	Scheme 1			
	West	West	West	West
$WTaxrate$	0.385***	0.308***	0.321***	0.357***
	(0.046)	(0.047)	(0.047)	(0.046)
TaxFed	-0.026	-0.016	-0.010	-0.012
	(0.016)	(0.016)	(0.016)	(0.016)
Personal Income	6.0e-09**	3.98e-09	3.88e-09	4.97e-09*
	(2.89e-09)	(2.81e-09)	(2.84e-09)	(2.85e-09)
Democrat_House		0.042***		
		(0.006)		
Democrat_Senate			0.031***	
			(0.005)	
Political Dummy				0.005***
				(8.97e-04)

Note: These are SAR Panel estimates with fixed-effect of the parameters in Eq. (2).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Table 9: Tax competition regressions, SAR Panel with spatial fixed effect

	Scheme 2			
	West	West	West	West
$WTaxrate$	0.346***	0.265***	0.278***	0.314***
	(0.043)	(0.044)	(0.044)	(0.043)
TaxFed	-0.035**	-0.024	-0.019	-0.021
	(0.017)	(0.016)	(0.016)	(0.017)
Personal Income	7.22e-09**	4.99e-09*	4.97e-09*	6.15e-09*
	(2.93e-09)	(2.84e-09)	(2.88e-09)	(2.88e-09)
Democrat_House		0.043***		
		(0.006)		
Democrat_Senate			0.032***	
			(0.005)	
Political Dummy				0.005***
				(9.07e-04)

Note: These are SAR Panel estimates with fixed-effect of the parameters in Eq. (2).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Table 10: Tax competition regressions, SAR Panel with spatial fixed effect

	Scheme 1			
	Northeast	Northeast	Northeast	Northeast
$WTaxrate$	-0.000***	-0.000***	-0.000***	-0.000***
	(5.08e-07)	(5.08e-07)	(5.08e-07)	(5.08e-07)
TaxFed	5.126***	4.800***	4.420***	4.820***
	(1.168)	(1.810)	(1.161)	(1.170)
Personal Income	1.000***	1.000***	1.000***	1.000***
	(5.20e-07)	(5.21e-07)	(5.18e-07)	(5.18e-07)
Democrat_House		0.604		
		(0.389)		
Democrat_Senate			1.136***	
			(0.313)	
Political Dummy				0.126**
				(0.062)

Note: These are SAR Panel estimates with fixed-effect of the parameters in Eq. (2).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Table 11: Tax competition regressions, SAR Panel with spatial fixed effect

	Scheme 2			
	Northeast	Northeast	Northeast	Northeast
$WTaxrate$	-0.000***	-0.000***	-0.000***	-0.000***
	(3.69e-07)	(3.69e-07)	(3.69e-07)	(3.69e-07)
TaxFed	6.132***	5.106***	5.016***	5.561***
	(1.241)	(1.222)	(1.207)	(1.229)
Personal Income	1.000***	1.000***	1.000***	1.000***
	(5.27e-07)	(5.14e-07)	(5.20e-07)	(5.21e-07)
Democrat_House		1.898***		
		(0.411)		
Democrat_Senate			1.794***	
			(0.331)	
Political Dummy				0.231***
				(0.066)

Note: These are SAR Panel estimates with fixed-effect of the parameters in Eq. (2).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Estimation results are not only consistent with those from OLS regression, but also show a sharper contrast in the degrees of capital tax competition.

Both neighboring schemes' results suggest the following: there exists a significant pattern of tax competition in the South and West under all specifications. Tax competition is positive but insignificant in the Midwest under most specifications, except one estimation with population adjusted neighbors. For the Northeast, no pattern of tax competition exists under all specifications.

To summarise, state capital tax competition is much stronger as well as more significant in the South and West where population have been growing faster, than that in the Midwest and Northeast with lower popoulation growth rates.

Moreover, the SAR panel estimation is more efficient, compared to OLS estimation.

3.3 Effect of population growth on capital tax competition

States in the South and West have been experiencing faster population growth than states in the Midwest and Northeast[7]. I examine whether the higher population growth rate induces stronger tax competition.

I use a high-order spatial autoregressive (SAR) panel model with fixed effects to estimate the effect of population growth rate on the degree of tax competition.

$$\begin{aligned} Y_{nt} &= \lambda_1 W_{1n} Y_{nt} + \lambda_2 W_{2n} Y_{nt} + X_{nt}\beta + u_n + \epsilon_{nt} && (3) \\ t &= 1, 2, ..., T, && (4) \end{aligned}$$

where $Y_{nt} = (y_{1t}, y_{2t}, ..., y_{nt})'$ is an $n \times 1$ vector of own state tax rates, W_{1n} is an $n \times n$ nonstochastic weighting matrix, $W_{2n} = G_n W_{1n}$, G_n is an $n \times n$ matrix with diagonal entries equal to the time-averaged population growth rates of each state. X_{nt} is an $n \times k$ vector of exogenous time varying variables, β is a $k \times 1$ vector of parameters, u_n is an $n \times 1$ vector of fixed-effect errors, and $\epsilon_{nt} = (\epsilon_{1t}, \epsilon_{2t}, ..., \epsilon_{nt})'$ is an $n \times 1$ vector of random errors. n is the number of states in one area, T is the number of years and k is the number of exogeneous state-dependent exogeneous variables included.

Thus, $\lambda_1 + \lambda_2 G_n$ represents the degree of tax competition and the coefficient λ_2 captures how population growth rate affects the degree of tax competition.

Followed by Lee and Yu (2014), GMM estimation is applied through a transformation approach to take account of the fixed effects. $[F_{T,T-1}, \frac{1}{\sqrt{T}} l_T]$ is the orthonormal matrix of eigenvectors of $J_T = (I_T - \frac{1}{T} l_T l_T')$, and $F_{T,T-1}$ is composed of the eigenvectors corresponding to all eigenvalues equal to one, so $F_{T,T-1}$ is $T \times (T-1)$. The variables are transformed as follows: $[Y^*_{n1}, Y^*_{n2}, ..., Y^*_{nT-1}] = [Y_{n1}, Y_{n2}, ..., Y_{nT}] F_{T,T-1}$, $[X^*_{n1}, X^*_{n2}, ..., X^*_{nT-1}] = [X_{n1}, X_{n2}, ..., X_{nT}] F_{T,T-1}$,and $[\epsilon^*_{n1}, \epsilon^*_{n2}, ..., \epsilon^*_{nT-1}] = [\epsilon_{n1}, \epsilon_{n2}, ..., \epsilon_{nT}] F_{T,T-1}$.

With the fixed effects eliminated, the estimated equation becomes:

$$\begin{aligned} Y^*_{nt} &= \lambda_1 W_{1n} Y^*_{nt} + \lambda_2 W_{2n} Y^*_{nt} + X^*_{nt}\beta + \epsilon^*_{nt} && (5) \\ t &= 1, 2, ..., T-1, && (6) \end{aligned}$$

[7]Statistics of population growth rates are summarized in Appendix II.

I then apply 2SLS estimation with optimum instrumental variables (IVs) chosen as suggested by Kelejian and Prucha (1998)[8]. The estimated results are summarized below.

Table 12: Tax competition regressions, high-order SAR Panel with spatial fixed effect

	Scheme 1			
$WTaxrate$	0.006	0.021	-0.044	0.012
	(0.170)	(0.166)	(0.179)	(0.169)
$G*WTaxrate$	18.979*	14.770	22.864*	14.812
	(11.303)	(10.292)	(11.917)	(9.811)
TaxFed	-0.024	-0.033*	-0.034**	-0.032*
	(0.017)	(0.017)	(0.017)	(0.017)
Personal Income	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Democrat_House	0.031***			0.009
	(0.007)			(0.009)
Democrat_Senate		0.035***		0.026***
		(0.006)		(0.007)
Political Dummy			0.005***	0.001
			(0.001)	(0.001)
Missing_Political	0.033***	0.037***	0.023***	0.038***
	(0.006)	(0.006)	(0.004)	(0.006)

Note: These are high-order SAR estimates with fixed-effect of the parameters in Eq. (5).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

[8]The procedure of choosing optimum IVs are included in Appendix III.

Table 13: Tax competition regressions, high-order SAR Panel with spatial fixed effect

	Scheme 2			
$WTaxrate$	-0.061	-0.081	-0.167	0.077
	(0.193)	(0.186)	(0.220)	(0.190)
$G * WTaxrate$	34.432**	31.984**	42.868***	21.784*
	(13.632)	(14.054)	(16.163)	(12.387)
TaxFed	-0.024	-0.032*	-0.035*	-0.029
	(0.018)	(0.018)	(0.018)	(0.018)
Personal Income	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Democrat_House	0.028***			0.006
	(0.008)			(0.009)
Democrat_Senate		0.032***		0.025***
		(0.007)		(0.007)
Political Dummy			0.005***	0.001
			(0.001)	(0.001)
Missing_Political	0.028***	0.032***	0.019***	0.033***
	(0.006)	(0.006)	(0.004)	(0.006)

Note: These are high-order SAR estimates with fixed-effect of the parameters in Eq. (5).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

As shown in Table 12 and 13, there exists tax competition ($\lambda_1 + \lambda_2 \cdot G > 0$). Moreover, specifications under both neighboring schemes show that λ_2 is positive and significant. With the population weighted neighboring scheme, this result is more significant. States with higher population growth rates compete in a much stronger manner than those with lower population growth rates.

This can be also shown in Figure 3 where representative states are marked.

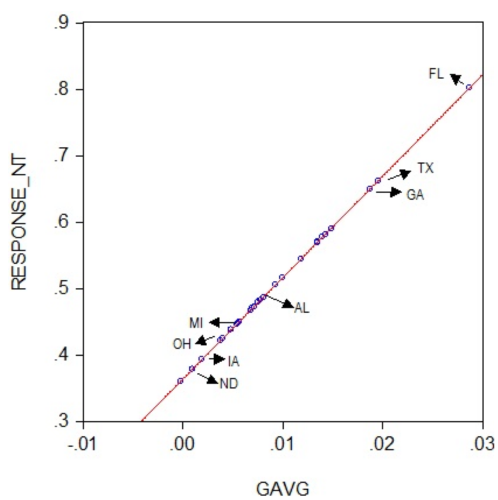

Figure 3: Response Coefficients and Population Growth Rates

Tax rates at federal level affect own state tax rates negatively in many estimation results.

3.4 Response of capital level to taxes

Another key empirical finding is on capital allocation among competing states, and how it is affected by capital tax rates and population growth rates.

To show that competition over capital leads to the observed patterns of tax interactions among states, I estimate an equation relating tax base to tax rates in own state and neighboring states, as in Brett and Pinkse (2000). This is also vital in explaining the theoretical channel in Section IV.

I run one panel of 48 states in Midwest, South, West and Northeast with fixed effects:

$$\log(k_{st}) = \alpha + \beta_1 \cdot OTR_{st} + \beta_2 \cdot (g_{st} \cdot OTR_{st}) + \lambda_1 \cdot TN_{st} + \lambda_2 \cdot (g_{st} \cdot TN_{st}) + \gamma \cdot TF_t + \mathbf{X}_{st} \cdot \tau + u_s + \epsilon_{st} \tag{7}$$

where k_{st} denotes capital per cap in state s at time t, OTR_{st}, TN_{st}, and TF_t are capital tax rates of own state, neighbors' average, and federal government, respectively. g_{st} is the population growth rate in state s at time t, and $\mathbf{X}$ is a row vector of exogenous explanatory variables, with macroeconomic and political variables previously defined. u_s is the fixed effect.

This estimates how own state capital level responds to changes in own state capital tax rates and neighbor states' capital tax rates. Moreover, the influence of population growth rates on the response of capital levels to tax rates is also examined. I first isolate the response to own tax rates, including the interacting term $g_{st} \cdot OTR_{st}$ and focusing on whether a faster population growth affects the response of capital allocation to changes in own state tax rates[9]. I continue to isolate the response to neighbors' tax rates, including the interacting term $g_{st} \cdot TN_{st}$ and testing whether faster population growth affects how much capital responding to changes in neighbors' tax rates[10]. Then I combine the responses to own state and neighbors' tax rates and include both interacting terms $g_{st} \cdot OTR_{st}$ and $g_{st} \cdot TN_{st}$ in the regression.

Both neighboring schemes are applied in the estimation.

Details about data source and variable definition of capital level are presented in Appendix II.

The results are qualitatively identical and lead to the same conclusions whether the responses are isolated or not. Thus, I present below the result of combined responses to own state and neighbors' tax rates, and how the responses are influenced by population growth rates.

[9] Results for this part is presented in Appendix IV.

[10] Results for this part is presented in Appendix IV.

Table 14: Capital allocation regression.
Dependent variables: log capital per cap

	Scheme 1			Scheme 2		
Specifications	II	III	IV	II	III	IV
Explanatory Variables						
OwnTax	-1.899***	-1.916***	-1.925***	-2.245***	-2.256***	-2.267***
	(0.188)	(0.188)	(0.188)	(0.191)	(0.191)	(0.190)
Growth×OwnTax	173.486***	172.769***	171.508***	231.332***	230.867***	228.910***
	(15.330)	(15.355)	(15.341)	(14.861)	(14.872)	(14.872)
TaxNeighbor	-1.639***	-1.685***	-1.710***	-1.575***	-1.585***	-1.613***
	(0.261)	(0.259)	(0.258)	(0.270)	(0.269)	(0.269)
Growth×TaxNeighbor	251.014***	251.030***	250.503***	176.163***	175.173***	173.904***
	(18.849)	(18.852)	(18.842)	(20.358)	(20.397)	(20.322)
TaxFed	0.108**	0.099*	0.090*	0.079	0.075	0.064
	(0.054)	(0.054)	(0.054)	(0.055)	(0.056)	(0.055)
log Personal Income	0.269***	0.270***	0.270***	0.266***	0.267***	0.267***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Democrat_House	-0.014			-0.007		
	(0.016)			(0.016)		
Democrat_Senate		0.005			0.004	
		(0.014)			(0.015)	
Political Dummy			0.005*			0.006**
			(0.003)			(0.003)
Missing_political	-0.044*	-0.032	-0.026	-0.048*	-0.040	-0.032
	(0.026)	(0.026)	(0.024)	(0.026)	(0.026)	(0.025)
Constant	7.273***	7.260***	7.260***	7.318***	7.311***	7.310***
	(0.022)	(0.026)	(0.020)	(0.023)	(0.023)	(0.021)

Note: These are least squares estimates with fixed-effect of the parameters in Eq. (7).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Note that $\beta_1 + \beta_2 \cdot g < 0$ and $\lambda_1 + \lambda_2 \cdot g > 0$ when evaluated at the sample mean of time-average population growth rate. This shows that $\frac{\partial k_i}{\partial t_i} < 0$ and $\frac{\partial k_i}{\partial t_j} > 0, i \neq j$, which means that own state capital level responds negatively to a change in its own tax rate, while positively to a change in its neighbors' average tax rate[11].

Moreover, the degree of how much tax rates can influence capital allocation depends on population growth rate. As $\beta_2 > 0$ and $\lambda_2 > 0$, a higher population growth rate reduces the magnitude of own tax rate's effect on own capital level, while increases the magnitude of neighbors' tax rates' effect on own capital level.

Federal tax rates' effect on capital allocation is significantly positive in most results but insignificant in some.

4 Benchmark Model

4.1 Tax Competition

There are two periods in the model. A nation is divided into two states, each of which is populated by a large number of identical residents in each period. Labor is immobile and grows at the same rate g in each state. Capital is perfectly mobile between states. Using labor and capital in the same production function, a single homogeneous good is produced in each state.

Each household in both states is endowed with income e in the first period, and saves for period 2. In the second period, each household earns labor income and receives the return from saving. Denote K_i, L_i as the aggregate level of capital and labor located in state i at period 2, $i = 1, 2$. The production function $F(K_i, L_i)$ has constant returns to scale, is concave in both inputs and twice continuously differentiable. The production function can be written in intensive form $f(k_i)$, where k_i is capital per worker at period 2.

Normalizing the price of the private good to one. Capital is taxed in each state with the unit tax rate t_i, $i = 1, 2$. Due to mobility of capital, net-of-tax returns are equalized between jurisdictions:

$$f'(k_1) - t_1 = f'(k_2) - t_2 = \rho \tag{8}$$

where ρ denotes this uniform net return. These non-arbitrage conditions define the demand for capital in each state $k_i = k(\rho + t_i)$, with $k'(\rho + t_i) = \frac{1}{f''(k_i)} < 0$.

Residents in each state get utility from consuming both private goods and public goods in two periods, with total utility $u_i(x_i^1, z_i^1) + \beta u_i(x_i^2, z_i^2)$ where β is the discount factor, x_i^t and z_i^t are levels of private goods and public goods consumed by residents in state i at period t.

All tax revenue collected by the government in each state is spent on public goods. As capital is accumulated only in the second period, government provides public goods only at period 2. This public good can be either excludable ($z_i = t_i k_i$) or non-excludable shared by all ($z_i = t_i k_i L_i$).

[11] Consistent with the finding in Buettner (2003), the impact of local tax rate has a negative effect on tax base, while the average tax rate of adjacent neighboring jurisdictions has a positive effect if interacted with population size.

Households choose saving s to maximize

$$u_i(e - s_i) + \beta v_i((1 + \rho)s_i, z_i) \tag{9}$$

Following Keen and Kotsogiannis (2002), the representative household acts as both worker and investor, and utility function is assumed to be

$$u(e - s_i) + f(k_i) - k_i \cdot f^{'}(k_i) + (1 + \rho)s_i + \Gamma(z_i) \tag{10}$$

Assume utility functions are identical in two states.

First-order condition describes saving behavior $s_i(\rho, t_1, t_2)$, $i = 1, 2$, where $u^{'}(e - s_i) = (1 + \rho)$. Assume saving only depends on net return $s(\rho)$ with $s^{'}(\rho) \geq 0$.

Suppose states start with same population of labor L in the first period, and given that the growth rate of population is g for both states, the following market-clearing condition holds:

$$(1 + g)\sum k_i = \sum s(\rho) \tag{11}$$

So,

$$\frac{\partial \rho}{\partial t_i} = \frac{(1 + g)k'(\rho + t_i)}{\sum s^{'}(\rho) - (1 + g)\sum k'(\rho + t_i)} \tag{12}$$

Assuming $f^{"}(k_i) = \gamma < 0$[12], then

$$\frac{\partial \rho}{\partial t_i} = -\frac{1}{2 + \frac{(-\gamma)\sum s^{'}(\rho)}{1+g}} \in (-\frac{1}{2}, 0) \tag{13}$$

Compared to one-period model where total capital is fixed[13], a one unit change in tax rate affects net return by less with saving in this two-period model.

There are two effects associated with tax change in this model: capital reallocation effect and saving effect. As one state cuts tax, more capital inflow is attracted. In addition, the return of investing in that state is higher which stimulates more saving nationwide. This saving effect drives up total capital, and reduces $f'(k_i)$, thus the net effect on $\rho = f'(k_i) - t_i$ is less since change in tax not only reallocates capital between states but also affects total saving.

When $s^{'}(\rho) = 0$, $\frac{\partial \rho}{\partial t_i} = -\frac{1}{2}$, same as the result when total capital is exogenously fixed, since saving is independent of ρ and there is capital reallocation effect only.

With a higher population growth rate, a certain amount of increased saving needs to be shared with more people, which is known as "dilution effect". Thus, each household has a lower increase in k, leading to a smaller drop in $f'(k_i)$ and a bigger effect on ρ.

Lemma 1 *The magnitude of $\frac{\partial \rho}{\partial t_i}$, $\left|\frac{\partial \rho}{\partial t_i}\right|$, is positively dependent on g. Given a same amount of tax cut, net return on capital increases more in the states with a higher population growth*

[12] A standard assumption on production function with one example being quadratic production form, which is also assumed in Brueckner and Saavedra (2001).

[13] The results obtained in Hoyt (1989), Bucovetsky (1991) show that $\frac{\partial \rho}{\partial t_i} = -\frac{1}{N}$ where N is the number of total states. Only reallocation effect exists.

rate.

In the extreme case where $g \to +\infty$, $\frac{\partial \rho}{\partial t_i} = -\frac{1}{2}$, same result as when $s'(\rho) = 0$. Only allocation effect remains when population grows too rapidly. Given any amount of total saving, capital is thinly spread out and each resident gets an insignificant share, the change in tax rate only affects the allocation of capital between the two states. To summarize, a higher g reduces saving effect.

Utilizing equations (8) and (13),

$$\frac{\partial k_i}{\partial t_i} = \frac{1}{\gamma} \cdot \frac{1 + \frac{(-\gamma)\sum s'(\rho)}{1+g}}{2 + \frac{(-\gamma)\sum s'(\rho)}{1+g}} < 0 \tag{14}$$

$$\frac{\partial k_i}{\partial t_j} = \frac{1}{-\gamma} \cdot \frac{1}{2 + \frac{(-\gamma)\sum s'(\rho)}{1+g}} > 0, i \neq j \tag{15}$$

Different from one-period model[14], there is asymmetric effect on capital from own tax cut and neighbor's tax cut, where $\left|\frac{\partial k_i}{\partial t_i}\right| \geq \frac{\partial k_i}{\partial t_j}$. And if $s'(\rho) > 0$, $\left|\frac{\partial k_i}{\partial t_i}\right| > \frac{\partial k_i}{\partial t_j}$. A change in own tax rate affects capital by more in magnitude than a neighbor's cut tax.

There are two effects associated with a tax cut in a state: reallocation effect transferring capital from the state to the tax-cut state; and saving effect which increases total capital stock nationwide. Obviously, reallocation effect increases k in one state (the state which initiates a tax cut), and reduces k in the other state by the same amount if total capital is fixed, which is the result obtained in one-period model. The saving effect, however, increases k in both states, leading to a further increase in k of the tax-cut state, and compensating some loss in k of the other state. Therefore, $\left|\frac{\partial k_i}{\partial t_i}\right|$ is higher than $\left|\frac{\partial k_i}{\partial t_j}\right|$ with saving in the model.

Lemma 2 $\left|\frac{\partial k_i}{\partial t_i}\right|$ *is negatively related to g, while* $\left|\frac{\partial k_i}{\partial t_j}\right|$ *is positively related to g.*

As a higher g results in a bigger increase in ρ given the same amount of tax cut (Lemma 1), k increases by less in the state which initiates the tax cut, as more people have to share the total capital. Similarly, as the new equilibrium net return ends up at a higher value, k in the other state drops by more. This is due to the increased total saving has to be shared by more, so each gets compensated by less.

This theoretical result is consistent with the empirical finding in Section II, and the dilution effect is verified both empirically and theoretically.

Each state government plays Nash with its neighboring state. Starting with the case of excludable public goods [15], government is benevolent and chooses its own capital tax rate t_1 to maximize aggregate utility in two periods.

Each government solves:

[14] In Hoyt (1989), for instance, $\frac{\partial k_i}{\partial t_i} = -\frac{\partial k_i}{\partial t_j}$.

[15] The case of partially-excludable public goods is discussed in Section 5.

$$\max_{t_i}\ u(e-s_i(\rho(t_1,t_2)))+f(k_i(t_1,t_2))-k_i(t_1,t_2)\cdot f^{'}(k_i(t_1,t_2))+(1+\rho(t_1,t_2))s_i(\rho(t_1,t_2))+\Gamma(t_i\cdot k_i(t_1,t_2)) \tag{16}$$

Taking FOC,

$$s_i\cdot\frac{\partial\rho}{\partial t_i}-f^{''}(k_i)\cdot k_i\frac{\partial k_i}{\partial t_i}+\Gamma_z\cdot(k_i+t_i\frac{\partial k_i}{\partial t_i})=0 \tag{17}$$

Suppose $\Gamma_z=\eta>0$[16] and $s^{'}(\rho)$ is not a function of ρ. Then utilizing equations (13), (14) and (15), the response action is:

$$\frac{\partial t_1}{\partial t_2}=-1+\frac{\eta}{\gamma}\cdot\frac{2-A+\frac{A-1}{\eta}}{A^2s'(\rho)+\frac{2\eta}{\gamma}+\frac{2\eta}{-\gamma}A-\frac{(1-A)^2}{\gamma}} \tag{18}$$

where $A=\frac{1}{2+\frac{(-\gamma)\sum s^{'}(\rho)}{1+g}}\ \epsilon\ (0,\frac{1}{2})$ and $\frac{\partial A}{\partial g}>0$.

Proposition 1 *As long as the value on public goods is high enough, i.e. $\eta>\underline{\eta}$, there exists tax competition where $\frac{\partial t_1}{\partial t_2}>0$.*

From equation (17), first-order condition $\eta\cdot k_i=\eta\cdot(-t_i\frac{\partial k_i}{\partial t_i})+s\cdot(-\frac{\partial\rho}{\partial t_i})+\gamma\cdot k_i\frac{\partial k_i}{\partial t_i}$ implies that given neighbor's tax rate t_2, own tax rate is chosen by equalizing the cost of a tax cut and the benefit of a tax cut. The cost of a tax cut is the loss in utility from public goods, as the government collects less revenue from each unit of capital, while the benefit combines an increased tax base from capital inflow contributing to higher utility from public goods, a higher return from saving made by households, with an extra benefit of a tax cut, increasing wage income by attracting more capital to production.

The threshold value is $\underline{\eta}=\max(1,\frac{A^2s^{'}(\rho)(-\gamma)}{2(1-A)}+\frac{1-A}{2})$. As $s^{'}(\rho)$ increases, the value governments impose on public goods needs to be higher to initiate tax competition. From cost-benefit analysis, when neighbor cuts tax, there is reallocation effect resulting in capital outflow. Hence, at the previously chosen tax rate, the cost of a tax cut drops with a lower level of capital base, which means the potential revenue loss from cutting tax reduces. On the other hand, whenever $s^{'}(\rho)>0$, saving nationwide increases after a tax cut in neighboring state, which increases the benefit of cutting own tax as consumption increases with a higher return from savings. The benefit from higher wage income, however, decreases with a lower capital base, as wage positively depends on capital level. And the benefit from higher public goods remains unchanged. And own state should compete with neighbor by cutting own tax rate, as long as reducing tax brings net benefit. As the net change in benefit is ambiguous, it can be negative, and if η is too small, the drop in benefit might even exceed that in cost, leading to cost of tax cut higher than its benefit, and own tax rate is raised as a result of neighboring tax cut.

Moreover, marginal utility (MU) of a tax increase equals $\eta\cdot k_i-\eta\cdot(-t_i\frac{\partial k_i}{\partial t_i})-s\cdot(-\frac{\partial\rho}{\partial t_i})-\gamma\cdot k_i\frac{\partial k_i}{\partial t_i}$, and $\frac{\partial MU}{\partial t}=\frac{2\eta(1-A)-(1-A)^2}{\gamma}+A^2s^{'}(\rho)$. Interior solution is attained whenever $\frac{\partial MU}{\partial t}<0$.

[16] As is assumed in Brueckner and Saavedra (2001).

In the case of $s^{'}(\rho) > 0$, however, $\frac{\partial MU}{\partial t}$ can be positive if η is relatively small compared to the value of $s^{'}(\rho)$, then utility function is convex with corner solution. The intuition is when the government values little on public goods, the consumption from saving as well as wage income is valued more. The government tends to reduce the tax rate to the bottom such that the return gained from saving increases to the utmost, without much loss in public goods. Thus, only the case where $\eta > \underline{\eta}$ is considered, so that the interior solution is obtained.

As shown from the results in Section II, there exists tax competition in areas in the U.S., which implies that the value on public goods by the government is sufficiently high.

Furthermore, from the equation of $\underline{\eta}$, this threshold value increases with population growth rate g when $s^{'}(\rho) > 0$, i.e. the value on public goods needs to be higher to induce tax competition. From Lemma 1, a higher population growth rate leads to a stronger effect on net return from any tax change, implying that cutting tax brings higher return on saving. Combined with Lemma 2, a higher population growth rate results in a smaller effect on own capital level after own tax change, implying that the degree of capital inflow is lessened even with tax cut, leading to a lower level of potential gain in public goods provision. Unless the value on public goods is sufficiently high, $\frac{\partial MU}{\partial t}$ is positive. Otherwise, states are better off benefiting from a higher saving return from neighbors' cutting tax.

Proposition 2 *A higher population growth rate g leads to stronger tax competition whenever there exists tax competition, i.e.* $\frac{\partial(\frac{\partial t_1}{\partial t_2})}{\partial g} > 0$ *whenever* $\eta > \underline{\eta}$.

Applying equation (17) again, after neighbor's cutting tax rate, there is capital outflow leading to a reduction in the cost of own tax cut. Moreover, if $s^{'}(\rho) > 0$, saving increases after a tax cut, leading to an increase in the benefit of own tax cut on the right-hand side. Since benefit exceeds cost, own state needs to cut tax rate.

From Lemma 1 and Lemma 2, a higher g leads to a stronger response in both net return and reduction in capital after neighbor's cutting tax, widening the gap between the benefit and the cost of tax cut. In addition, a higher population growth rate results in a smaller increase on own capital level after own tax cut. Thus, states compete in a more fierce method.

As a higher population growth rate reduces saving effect, residents obtain only a smaller share of increased saving. Hence, with a smaller "pie" for each resident, governments compete more strongly for the mobile capital.

4.2 Social Planner

One question is whether inefficiency arises from tax competition, and how population growth rate g affects the magnitude of the inefficiency.

Consider a social planner's problem maximizing the total welfare of two states' residents:

$$\max_{t} \; u(e - s(\rho(t))) + f(k(t)) - k(t) \cdot f^{'}(k(t)) + (1 + \rho(t))s(\rho(t)) + \Gamma(t \cdot k(t)) \tag{19}$$

and a coordinated change in both states' tax rates affects net return by:

$$\frac{\partial \rho}{\partial t} = \frac{\partial \rho}{\partial t_i} \cdot 2 = -\frac{1}{1 + \frac{(-\gamma)s'(\rho)}{1+g}} \in (-1, 0) \tag{20}$$

The effect of a coordinated increase in both state taxes gives $s \cdot \frac{\partial \rho}{\partial t} + \Gamma_z \cdot (k + t\frac{\partial k}{\partial t}) - kf''(k)\frac{\partial k}{\partial t}$, comparing with the result of corresponding symmetric equilibrium by substracting equation (17) from it: $s \cdot (\frac{\partial \rho}{\partial t} - \frac{\partial \rho}{\partial t_i}) + (\Gamma_z \cdot t - kf''(k)) \cdot (\frac{\partial k}{\partial t} - \frac{\partial k_i}{\partial t_i}) = (s + \frac{\Gamma_z \cdot t}{\gamma} - k) \cdot (\frac{\partial \rho}{\partial t} - \frac{\partial \rho}{\partial t_i})$. And from equation (20), $\frac{\partial \rho}{\partial t} - \frac{\partial \rho}{\partial t_i} = -\frac{1}{2 + \frac{2(-\gamma)s'(\rho)}{1+g}} < 0$.

Proposition 3 *The tax competition allocation is efficient if and only if* $s + \frac{\Gamma_z \cdot t}{\gamma} - k = 0$*. Tax rates from uncoordinated tax setting are too high if* $s + \frac{\Gamma_z \cdot t}{\gamma} - k > 0$*; and tax rates from competition are too low if* $s + \frac{\Gamma_z \cdot t}{\gamma} - k < 0$*.*

Consistent with Keen and Kotsogiannis (2004), whether uncoordinated chosen tax rates in a free market are too high or too low depends on the elasticities of the demand for capital and the value on public goods. When $|\gamma|$ is too small, marginal productivity is less sensitive to change in k, implying that after neighbor cutting tax, capital outflow would be more significant. Together with a higher value on public goods, own state has to fight much strongly in order to provide public goods, resulting in efficiency loss from too much competition.

Proposition 4 *The degree of inefficiency is higher when the population growth rate* g *is higher.*

Whether inefficiency arises from a tax rate that is too high or too low than socially optimal, a higher population growth g widens the gap between the effect on net return from a competitive and a coordinated tax cut.

When value on public goods is not large enough to initiate competition, states take advantage of higher net return from neighbors' lower tax and do not lower taxes accordingly. Each state ignore the positive externality it confers on its neighbors' net return by cutting tax, and as a higher population growth rate g magnifies the effect on net return from one unit tax cut, the loss in efficiency is bigger.

Whenever there exists tax competition, while competing over capital pool to provide public goods, each state ignores the negative externality imposed on its neighbors' capital level. As a higher population growth increases this externality, neighbors are forced to fight stronger.

5 Conclusion

The empirical contribution of this paper is to first quantify the degree of tax competition among states in the US, applying MLE estimation of the SAR panel data model with fixed-effects. Another empirical finding is that states in the South and West compete in setting capital tax rate much more strongly than states in Midwest and Northeast. One explanation, which is empirically tested in this paper applying a high-order SAR panel data estimation with fixed-effects, is that population growth rates are much higher in the South and West than the growth rates in the Midwest and Northeast.

The supporting related empirical finding is that capital allocation is affected by tax rates in own state and neighboring states. Amount of capital inflow to own state negatively depends on own tax rate while positively depends on neighbors' tax rates. Moreover, the magnitude of tax rates' effect on capital allocation significantly depends on population growth rates. This verifies the "capital dilution" effect among the states in the US.

A model with intertemporal saving decision can account for these empirical facts. Different from most tax competition literature, the pool of total capital that states compete over is not fixed. Whenever one state's tax cutting increases the net return of saving, households save more for the second period. A high population growth rate increases the gap between the two periods' population, people who save and people who share the savings. Thus, faster population growth dilutes the increase in capital by more, leading to a lower increase in capital per cap for the tax-cut state and a bigger loss in capital per cap in its neighborhood. The same unit tax cut brings benefit by less and cost by more, leading to states cutting tax more fiercely and stronger strategic interaction among each other.

Regarding social efficiency, a higher population growth rate leads to greater inefficiency cost. The policy implication is whenever tax competition is observed, it is of more importance to regulate those states experiencing faster population growth.

For further study, spatial interaction estimation can also be applied to examine the strength of competition with geographic neighbors and economic neighbors at state-level, in the spirit of Pinkse et. al (2002).

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Appendix I

Table I State Abbreviations of the major four areas in the U.S.

Midwest	South	West	Northeast
IL	FL	AZ	CT
IN	GA	CA	RI
IA	MD	CO	NJ
KS	NC	ID	PA
MI	SC	MT	NY
MN	VA	NM	MA
MO	WV	NV	VT
NE	DE	OR	NH
ND	AL	UT	ME
OH	KY	WA	
SD	MS	WY	
WI	TN		
	AR		
	LA		
	OK		
	TX		

Appendix II

In this section, the data source for and definition of each variable is provided. The panel dataset is for 48 contiguous states from 1958 to 2007.

A. Capital tax rate:

The average capital tax rate for each state s at time t is defined as follows,

$\mathrm{ACTR}_{s,t} = \frac{\text{capital tax revenue}_{s,t}}{\text{taxable capital income}_{s,t}}$

From US Census Bureau, I sum up the two main sources of capital tax revenue: property tax, corporate net income tax.

capital tax revenue$_{s,t}$ =property tax revenue$_{s,t}$+corporate net income tax revenue$_{s,t}$

Code T01 Property Taxes

Taxes imposed on ownership of property and measured by its value.

Definition: Three types of property taxes, all having in common the use of value as a basis for the tax:

• General property taxes, relating to property as a whole, taxed at a single rate or at classified rates according to the class of property.

Property refers to real property (e.g., land and structures) as well as personal property; personal property can be either tangible (e.g., automobiles and boats) or intangible (e.g., bank accounts and stocks and bonds).

• Special property taxes, levied on selected types of property (e.g., oil and gas properties, house trailers, motor vehicles, and intangibles) and subject to rates not directly related to general property tax rates.

• Taxes based on income produced by property as a measure of its value on the assessment date.

Code T41 Corporation Net Income Taxes

Definitions: Taxes on corporations and unincorporated businesses (when taxed separately from individual income), measured by net income,whether on corporations in general or on specific kinds of corporations, such as financial institutions.

To construct taxable capital income, I use the summation of personal dividend income, personal interest income, and rental income of persons with capital consumption adjustment. This series of taxable capital income is obtained from BEA, where

taxable capital income$_{s,t}$ =personal dividend income$_{s,t}$+personal interest income$_{s,t}$+rental income$_{s,t}$

Personal dividend income is payments in cash or other assets, excluding the corporations' own stock, that corporations in the United States or abroad make to noncorporate stockholders who are U.S. residents.

Personal interest income is the interest income (monetary and imputed) from all sources that is received by individuals, by private and government employee retirement plans, by nonprofit institutions, and by estates and trusts.

The rental income of persons with capital consumption adjustment is the net current-production income of persons from the rental of real property except for the income of persons primarily engaged in the real estate business; the imputed net rental income received by owner-occupants of dwellings; and the royalties received by persons from patents, copyrights, and rights to natural resources. The estimates include BEA adjustments for uninsured losses to real estate caused by disasters, such as hurricanes and floods.

B. Control Variables

The series of federal effective capital gains tax rate from 1958 to 2007 is obtained from Tax Foundation. It is calculated as follows:

$\mathrm{ECTR}_t^{\mathrm{fed}} = \frac{\text{taxes paid on capital gains}_t}{\text{realized capital gains}_t}$

Personal income data are obtained from U.S. CENSUS Bureau.

Data of electoral outcomes are obtained from Council of State Governments-Book of States. For each state from 1958 to 2007, I collect the data "number of members in Lower House that are Democrat" (HD), "number of members in Lower House that are Republican" (HR), "number of members in Upper House that are Democrat" (SD) and "number of members in Upper House that are Republican" (SR).

The political environment variables are caluculated as follows:

For the fraction of state house that is Democrat, $\mathrm{D\_H}_{s,t} = \frac{\mathrm{HD}_{s,t}}{\mathrm{HD}_{s,t}+\mathrm{HR}_{s,t}}$;

for the fraction of state senate that is Democrat $\mathrm{D\_S}_{s,t} = \frac{\mathrm{SD}_{s,t}}{\mathrm{SD}_{s,t}+\mathrm{SR}_{s,t}}$;

and for the dummy variable, $\mathrm{d}_{s,t}$=2 if Democrat is majority in both State Lower House and Senate, $\mathrm{d}_{s,t}$=1 if either State Lower house or Senate has Democrat as majority, and $\mathrm{d}_{s,t}$=0 Republican is majority in both State Lower House and Senate.

For Nebraska from 1958-2007 and Minnesota from 1958-1973, members were selected in nonpartisan elections. I include missing variables to account for it.

C. Weighting Scheme

Scheme 1: For state i in each of the four areas (South, Midwest, West and Northeast), $w_{ij} = \frac{1}{K}$ if states i and j are located in the same area and share the same border geographically; and $w_{ij} = 0$ otherwise. K is the total number of contiguous states of state i in its area.

Scheme 2: For state i in each of the four areas (South, Midwest, West and Northeast), $w_{ij} = \frac{\text{timeavgpopu}_j}{\sum \text{timeavgpopu}_k}$ if states i and j are located in the same area and share the same border geographically; and $w_{ij} = 0$ otherwise. timeavgpopu_j is the average population size of state j from 1958 to 2007, and $\sum \text{timeavgpopu}_k$ is the sum of average population size from 1958 to 2007 of all the contiguous states of state i in its area.

D. Population

The series of population data for each state from 1958 to 2007 is obtained from U.S. CENSUS Bureau.

Table II.A Time-Average Population Growth Rates, 1958-2007

Midwest		South		West		Northeast	
IL	0.0056	FL	0.0287	AZ	0.0348	CT	0.0073
IN	0.0068	GA	0.0187	CA	0.0184	RI	0.0043
IA	0.0019	MD	0.0134	CO	0.0221	NJ	0.0079
KS	0.0054	NC	0.0148	ID	0.0174	PA	0.0026
MI	0.0055	SC	0.0135	MT	0.0075	NY	0.0032
MN	0.0092	VA	0.0140	NM	0.0165	MA	0.0053
MO	0.0069	WV	-0.0003	NV	0.0474	VT	0.0101
NE	0.0048	DE	0.0143	OR	0.0160	NH	0.0169
ND	0.0010	AL	0.0081	UT	0.0238	ME	0.0068
OH	0.0040	KY	0.0075	WA	0.0175		
SD	0.0038	MS	0.0068	WY	0.0106		
WI	0.0078	TN	0.0118				
		AR	0.0100				
		LA	0.0071				
		OK	0.0093				
		TX	0.0195				

Table II.B Group and Time Averaged Population Growth Rate, with Standard Deviation

Midwest	South	West	Northeast
0.0052	0.0123	0.0211	0.0072
(0.0024)	(0.0066)	0.0112	0.0044

E. Capital

Data of capital series at the state level is obtained from Garofalo and Yamarik (2002), and Yamarik (2012).

For year 1958-1990, capital at state level, denoted as K_{st}, is calculated as Net Private Capital Stock created through 1-digit SIC industries, using gross private investment of Net

Private Capital Stock created through 1-digit SIC industries and time-varying depreciation rate created through 1-digit SIC industries. The estimates are further revised because many farms declare losses, and thus propreitary income of agriculture was removed.

For year 1991-2008, capital K_{st} is calculated as Net Private Capital Stock created through 1-digit NAIS industries, using gross private investment of K1 using industry-specific time-varying depreciation rate created through 1-digit NAIS industries.

Thus,capital per cap $k_{st} = \frac{K_{st}}{L_{st}}$, where L_{st} is population of state s at time t from Appendix II.D.

Appendix III

Instrumental Variables

$Y^*_{nt} = \lambda_1 W_{1n} Y^*_{nt} + \lambda_2 W_{2n} Y^*_{nt} + X^*_{nt}\beta + \epsilon^*_{nt}$

And in this paper, $Y^*_{nt} = (\lambda_1 + \lambda_2 G_n) W_{1n} Y^*_{nt} + X^*_{nt}\beta + \epsilon^*_{nt}$, and it follows that $Y^*_{nt} = S_n^{-1} X^*_{nt}\beta + S_n^{-1}\epsilon^*_{nt}$, where $S_n = I_n - (\lambda_1 + \lambda_2 G_n) W_{1n}$.

Thus, the optimum IV matrix is $(X^*_{nt}, W_{1n} S_n^{-1} X^*_{nt})$.

Whenever λ_1 and λ_2 take the values so that S_n is invertible and expandable, optimum IVs can be chosen as $(W_{1n}(\lambda_1+\lambda_2 G_n) W_{1n} X^*_{nt}, W_{1n}(\lambda_1+\lambda_2 G_n) W_{1n}(\lambda_1+\lambda_2 G_n) W_{1n} X^*_{nt}, ...)$, and in this paper, $(W_{1n}X^*_{nt}, W^2_{1n}X^*_{nt}, W_{1n}G_nW_{1n}X^*_{nt}, W^3_{1n}X^*_{nt}, W_{1n}G_nW^2_{1n}X^*_{nt}, W^2_{1n}G_nW_{1n}X^*_{nt}, W_{1n}G_nW_{1n}G_nW_{1}$ is chosen as IVs.

Appendix IV

Table III.A: Capital allocation regression: Response to Own Tax. Scheme 1

Dependent variables: log capital per cap

Specifications	I	II	III	IV
Explanatory Variables				
OwnTax	-2.766***	-2.764***	-2.775***	-2.772***
	(0.184)	(0.184)	(0.184)	(0.184)
Growth×OwnTax	270.154***	270.280***	268.813***	268.460***
	(14.038)	(14.060)	(14.091)	(14.090)
TaxNeighbor	0.971***	0.977***	0.946***	0.986***
	(0.163)	(0.166)	(0.164)	(0.166)
Growth×TaxNeighbor				
TaxFed	0.149***	0.150***	0.140**	0.140**
	(0.056)	(0.056)	(0.056)	(0.056)
log Personal Income	0.264***	0.264***	0.265***	0.264***
	(0.002)	(0.002)	(0.002)	(0.002)
Democrat_House		-0.003		-0.032
		(0.015)		(0.022)
Democrat_Senate			0.015	0.036*
			(0.014)	(0.020)
Constant	0.404***	0.406***	0.395***	0.402***
	(0.019)	(0.021)	(0.021)	(0.021)

Note: These are least squares estimates with fixed-effect of the parameters in Eq. (4).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Table III.B: Capital allocation regression: Response to Neighbors' Taxes. Scheme 1
Dependent variables: log capital per cap

Specifications	I	II	III	IV
Explanatory Variables				
OwnTax	-0.186*	-0.188*	-0.217**	-0.217**
	(0.107)	(0.108)	(0.109)	(0.109)
Growth×OwnTax				
TaxNeighbor	-2.239***	-2.243***	-2.259***	-2.217***
	(0.237)	(0.239)	(0.238)	(0.239)
Growth×TaxNeighbor	347.450***	347.375***	345.911***	345.470***
	(16.479)	(16.492)	(16.509)	(16.508)
TaxFed	0.093*	0.093*	0.082	0.083
	(0.055)	(0.055)	(0.055)	(0.055)
log Personal Income	0.270***	0.270***	0.271***	0.271***
	(0.002)	(0.002)	(0.002)	(0.002)
Democrat_House		0.002		-0.030
		(0.015)		(0.022)
Democrat_Senate			0.020	0.040**
			(0.013)	(0.020)
Constant	0.339***	0.338***	0.328***	0.334***
	(0.019)	(0.021)	(0.021)	(0.022)

Note: These are least squares estimates with fixed-effect of the parameters in Eq. (4).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Table III.C: Capital allocation regression: Response to Own Tax. Scheme 2

Dependent variables: log capital per cap

Specifications	I	II	III	IV
Explanatory Variables				
OwnTax	-2.759***	-2.764***	-2.772***	-2.771***
	(0.185)	(0.185)	(0.185)	(0.185)
Growth×OwnTax	282.091***	281.352***	279.712***	279.746***
	(13.945)	(13.992)	(14.019)	(14.020)
TaxNeighbor	0.440***	0.422**	0.410**	0.426***
	(0.161)	(0.164)	(0.162)	(0.163)
Growth×TaxNeighbor				
TaxFed	0.127**	0.123**	0.114**	0.114**
	(0.056)	(0.056)	(0.056)	(0.056)
log Personal Income	0.264***	0.264***	0.264***	0.264***
	(0.002)	(0.002)	(0.002)	(0.002)
Democrat_House		0.010		-0.017
		(0.015)		(0.022)
Democrat_Senate			0.022	0.034*
			(0.014)	(0.020)
Constant	0.426***	0.420***	0.413***	0.416***
	(0.020)	(0.022)	(0.022)	(0.023)

Note: These are least squares estimates with fixed-effect of the parameters in Eq. (4).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Table III.D: Capital allocation regression: Response to Neighbors' Taxes. Scheme 2
Dependent variables: log capital per cap

Specifications	I	II	III	IV
Explanatory Variables				
OwnTax	-0.248**	-0.244**	-0.275**	-0.273**
	(0.106)	(0.107)	(0.108)	(0.108)
Growth×OwnTax				
TaxNeighbor	-2.069***	-2.065***	-2.078***	-2.052***
	(0.194)	(0.195)	(0.195)	(0.195)
Growth×TaxNeighbor	316.290***	316.729***	314.397***	315.535***
	(13.525)	(13.613)	(13.606)	(13.613)
TaxFed	0.139**	0.141**	0.129**	0.129**
	(0.054)	(0.055)	(0.055)	(0.055)
log Personal Income	0.266***	0.266***	0.266***	0.266***
	(0.002)	(0.002)	(0.002)	(0.002)
Democrat_House		-0.004		-0.039*
		(0.015)		(0.022)
Democrat_Senate			0.017	0.043**
			(0.013)	(0.020)
Constant	0.386***	0.389***	0.376***	0.384***
	(0.020)	(0.022)	(0.022)	(0.022)

Note: These are least squares estimates with fixed-effect of the parameters in Eq. (4).

Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.