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**Strategic Tax Competition:
An Experimental Study**

Sailesh Gunessee¹

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Keywords

Tax Competition, Experimental Economics, Asymmetry

Authors' affiliations

¹ Nottingham University Business School China

Address for correspondence

saileshsingh.gunessee@nottingham.edu.cn Tel: +86 574 8818 0231

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Sailesh Gunessee*

Nottingham University Business School China, 199 Taikang East Road, Ningbo 315100, China

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* *Telephone:* +86 574 8818 0231; *Fax:* +86 574 8818 0125.

E-mail: saileshsingh.gunessee@nottingham.edu.cn.

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1. Introduction

The topic of tax competition seems to have engineered a lot of debate both in the policy and academic circles¹. It describes the situation where independent jurisdictions compete noncooperatively over the taxation of mobile capital to influence its location. A conventional result of the strategic tax competition model is that taxes are set inefficiently lower than the coordinated tax rates (Zodrow and Mieszkowski, 1986; Wildasin, 1988 and Hoyt, 1991). Though this prediction still holds in the presence of asymmetry, characterised by differences in either population or preferences for the public good, added insights have been offered by asymmetric tax competition models. One salient finding is the difficulty to sustain any coordination, as different nations would set different tax rates even in equilibrium yielding different payoffs (Bucovetsky, 1991; Kanbur and Keen, 1993). This is even further demonstrated in a setting where countries interact repeatedly (Cardarelli, Taugourdeau and Vidal, 2002).

In this paper, we experimentally study the impact of a payoff advantage, symmetric payoff change and policymakers interaction on choices in tax competition games. This study is motivated by the fact that there is limited experimental work done to examine policy competition where decision makers are governments. The only study to our knowledge that fits this category is the work of Engelmann and Normann (2007) who experimentally examine the model of strategic trade policy². In their two-stage set-up governments choose to either subsidise or not, while firms compete in a Cournot duopoly choosing an output among a choice of four. The main question of their study is whether governments subsidise their firms. They find that in the laboratory governments rarely choose to subsidise. It is only when the decisions of firms are computer simulated that government choices converge to equilibrium.

While our study contributes to this policy competition literature, it also differs from the work of Engelmann and Normann. They are interested in the empirical validity of the trade

¹ See Zodrow (2003) and Wilson and Wildasin (2004).

² Previous empirical studies on tax competition have mostly used field data to focus on a different prediction of the theory, obtaining conflicting and inconclusive results (see Bretschger and Hettich, 2002; Devereux, Lockwood and Redoano, 2003).

policy model. In our case we are interested in studying behaviour under different tax policy scenarios (where payoffs are altered) and we thus examine if differences in behaviour emerge. As such the object of our study is different. Consequently as opposed to a 2x2 policy game, which is in effect a symmetric Prisoner's dilemma facing two governments, the policy competition in our experiment is richer. In studying these effects we are able to study not only different symmetric policy games but an asymmetric tax policy game.

The games used in this paper are derived using a simple strategic tax competition model. To operationalise our design we employ the preferences for the public good to derive two symmetric games and one asymmetric game. One of the symmetric games, which lower payoffs, is used as our benchmark. This game is compared respectively to a tax competition game where payoffs are asymmetric and a tax competition game where payoffs of both decision makers are symmetrically higher. Decisions in these games are also examined and compared when policymakers interact repeatedly as opposed to under a random pairing. Thus this design enables us to study whether asymmetry, payoff size effect and repeated interactions matter.

This paper is organised as follows. The second section presents the theoretical model and the experimental design. The results are then presented in section 3 and we leave it in section 4 to conclude.

2. Theory and Experimental Design

To keep the analysis tractable and for experimental design purposes we use specific functional forms and parameterise our model using the preference for the public good parameter γ .

2.1 Theoretical setup

The model considered is a simplified version of the STC model with two jurisdictions i and j , labelled as $i = A, B$ such that $i \neq j$, with the production function of each jurisdiction being quadratic in capital-labour ratio k_i

$$f(k_i) = k_i - \frac{1}{4}k_i^2 \quad (1)$$

and $f'(k_i)$ is the marginal product of capital or gross return, derived from the quadratic production function as

$$f'(k_i) = 1 - \frac{1}{2}k_i, \quad f''(k_i) = -\frac{1}{2} < 0 \quad (2)$$

The representative household's utility function³ is linear in private good consumption, C_i and public good consumption, G_i

$$U(C_i, G_i) = C_i + \gamma_i G_i, \quad \gamma_i > 1 \quad (3)$$

where γ_i denotes the preference for the public good of the representative household. A high γ implies the representative consumer has a strong preference or taste for the public good. Later the parameter γ will be used to setup different treatments for the experiment.

The representative household owns immobile labour and mobile capital which earns labour income, $f(k_i) - f'(k_i)k_i$ and capital income, $r\bar{k}_i$, which is used to finance private consumption

$$C_i = f(k_i) - f'(k_i)k_i + r\bar{k}_i \quad (4)$$

where \bar{k}_i stands for the initial fixed capital stock owned by the jurisdiction i . Assume that these capital endowment are initially normalised to one, such that $\bar{k}_i = \bar{k}_j = 1$. Hence, the fixed capital supply in the world is totalled to 2. Then, under the capital market clearing condition, equilibrium occurs when

$$\bar{k}_i + \bar{k}_j = k_i + k_j = 2 \quad (5)$$

Given capital is freely mobile across jurisdictions this implies the net-of-tax return, r , must be equal across jurisdictions

$$f'(k_i) - t_i = f'(k_j) - t_j = r \quad (6)$$

³ Cardarelli, Taugourdeau and Vidal (2002) use a similar functional form to define their representative consumer's utility function, where γ_i represents 'preferences for the public good'. However, their repeated interactions model differs from the mainstream model in that they assume the existence of a sunk cost to investing in capital abroad.

The public good in each jurisdiction is assumed to be solely financed by a per unit source-based tax on capital

$$G_i = t_i k_i \quad (7)$$

where t_i is the per unit tax in jurisdiction i . Equation (7) can also be interpreted as the budget constraint of each jurisdiction's government.

The objective of each jurisdiction is to set a tax rate that maximises their respective welfare function, $U(t)$ which we solve as $t^* = \arg \max_t U(t)$ {see Appendix A} to arrive at

$$t_i^* = \frac{3\gamma_i \gamma_j - \frac{3}{2}\gamma_i - \frac{5}{2}\gamma_j + 1}{3\gamma_i \gamma_j - \frac{1}{2}\gamma_i - \frac{1}{2}\gamma_j} \quad (8)$$

The expression defines the Nash equilibrium tax rate where each jurisdiction's equilibrium strategy to set taxes non-cooperatively is a best response to the other jurisdiction's equilibrium tax strategy and jurisdictions share the same production and objectives. Given the preference for the public good (γ) we can compute the equilibrium tax rate.

Bearing in mind that $\gamma > 1$, for the benchmark symmetric tax competition game we set $\gamma_A = \gamma_B = 2$. For the asymmetric game we have $\gamma_A = 3$ and $\gamma_B = 2$ and the second symmetric game $\gamma_A = \gamma_B = 3$. Therefore, in the asymmetric game only jurisdiction A faces a higher preference for the public good. In the second symmetric game both governments face symmetrically higher public good preferences.

These three games respectively yield symmetric equilibrium tax rates $t_A^* = t_B^* = 0.5$, asymmetric equilibrium tax rates $t_A^* = 0.613$ and $t_B^* = 0.548$, symmetric equilibrium tax rates $t_A^* = t_B^* = 0.667$. To keep things simple⁴, while maintaining all features of the tax competition model, we restrict the strategy sets to four tax options for each jurisdiction. The strategy set in the two symmetric games are $\{0.4, 0.5, 0.667, 1\}$, while that in the asymmetric

game is $\{0.548, 0.613, 0.67, 1\}$. The three reduced tax competition games are reported in Table 1.

**** TABLE 1 ABOUT HERE ****

The first and third matrix in Table 1 reproduces the welfare levels for the two symmetric jurisdictions for the sixteen possible pair of tax rates 0.4, 0.5, 0.667 and 1, while the second matrix depicts the asymmetric case (Case II: $\gamma_A = 3$ and $\gamma_B = 2$), for the tax options 0.548, 0.613, 0.667 and 1. The distinction between the three games is evident. In the two symmetric games the payoffs are the same for both jurisdictions, whereas in the asymmetric tax competition game welfare levels are distributed unequally. The asymmetry in welfare levels can be seen clearly. Policymaker A has higher payoffs compared to policymaker B . Jurisdiction A and jurisdiction B can be referred to as the ‘advantaged’ and ‘disadvantaged’ player correspondingly. The difference between the two symmetric games is the higher payoffs levels received by governments when they have higher preferences for the public good.

By examining the action pairs in the payoff matrix it can be seen that the tax pair (0.5, 0.5) satisfies the condition for a unique Nash equilibrium for the symmetric game, as each player’s strategy is the best response to the other’s. Analysing the various action pairs in the asymmetric game the Nash equilibrium boils down to being sub-optimal relative to the coordinated choices again. Under non-cooperative tax setting jurisdictions set taxes at (0.667, 0.667) in equilibrium in the third game. All in all, in these games as postulated by the strategic tax competition model *tax competition leads jurisdictions to set an inefficiently low source-based capital tax rate in equilibrium, relative to the coordinated tax rate*⁵.

⁴ As argued by Engelmann and Normann (2007) to avoid erratic decisions it is preferable to utilise a simple design.

2.2 Experimental setup

Procedure. This leads us to the actual design of our experiment. We had three initial treatments based on the three games: SYMLOW (symmetric treatment with $\gamma_A = \gamma_B = 2$), ASYM (asymmetric treatment with $\gamma_A = 3$ and $\gamma_B = 2$), and SYMHIGH (symmetric treatment with $\gamma_A = \gamma_B = 3$). These correspond in that order to our three tax competition games: symmetric with low payoffs, asymmetric with asymmetric payoffs and symmetric with high payoffs. These three treatments were run using a random matching protocol where players were randomly re-matched with a different participant every round. A session consisted of 20 rounds. We use SYMLOW as a benchmark and study the effect of payoff asymmetry (SYMLOW vs. ASYM) and the impact of payoff size change (SYMLOW vs. SYMHIGH) on behaviour.

As an additional test of behaviour we collected data on these games but with one alteration made to our experimental design. We allow the matching between players to change. Instead of having a participant paired randomly with a different participant every round, we have each subject being paired with the *same* person every round in a session (i.e. fixed matching). Participants in these new treatments, namely SYMLOWFIXED, ASYMFIXED and SYMHIGHFIXED, were informed of this clearly. In this case we are interested in studying the effect of repeated interactions on behaviour under a payoff advantage (SYMLOWFIXED vs. ASYMFIXED) and payoff size change (SYMLOWFIXED vs. SYMHIGHFIXED).

To minimise presentation (framing) effects, the experimental design employed a context free situation. This was done with the consideration that the terms ‘jurisdictions’ and ‘tax rates’ may be interpreted differently by some people. So the neutral set-up was presented to subjects such that jurisdictions *A* and *B* were respectively called ‘row player’ and ‘column player’ and tax rates were referred to as ‘options’⁶.

⁵ See Appendix B for a proof.

⁶ The evidence on framing effects is rather mixed. Alm, McClelland and Schulze (1992), in a tax evasion experiment, find that behaviour is unaffected as to whether neutral or with-context instructions are used. Instead, McCaffery and Baron (2004) who use web-based experiments to study attitudes

Implementation. The data from our experiment was collected at the University of Nottingham, UK, where subjects were recruited through e-mail shots from a mailing directory that comprises of undergraduate students from the entire university, who had indicated their willingness to be paid volunteers for experiments undertaken by the Centre for Decision Research and Experimental Economics (CeDEx). The whole experiment consisted of 12 sessions in all. The treatments with random matching (i.e SYMLOW, ASYM and SYMHIGH) had a total of 9 sessions with 3 sessions conducted for each treatment. Instead, for treatments SYMLOWFIXED, ASYMFIXED and SYMHIGHFIXED, data was collected for one session from each treatment. Eight subjects took part in each session, and no subject participated in more than one session. A total of 96 subjects took part in the experiment with 72 subjects in the random pairing treatments (9 sessions x 8 subjects per session) and 24 subjects in the fixed pairing treatments (3 sessions x 8 subjects per session). No subject participated in more than one session. Since *each session* of the random pairing treatments is regarded as one independent observation, thus there were three independent observations per treatment and a total of 9 independent observations considering all treatments with random pairing. In the fixed pairing treatments with one session of 8 subjects for each treatment, there is 12 independent observations, since in these treatments each *pair of subjects* represents one independent observation⁷.

Upon arrival, participants were seated at a computer terminal, where they were given a set of instructions {see Appendix C} and assigned the role of either a row player or a column player. After the instructions were read to them, subjects were asked to complete a question form to ascertain they understood the experiment.

towards taxation, document various forms of framing effects from their study confirming the idea that framing matters in the context of taxation. Abbink and Henning-Schmidt (2006) find that framing does not matter in a bribery experiment, prompting them to conjecture that a neutral frame already transmit the key features of a bribery situation.

⁷ The norm is to have at least a minimum of 3 independent observations.

Subjects were not allowed to communicate between themselves, such that all choices and feedback were made and received through the computer terminal. So, whom they were paired with remained unknown to the subjects. In each round, a subject chose from the four options 1, 2, 3 and 4⁸. At the end of each round, when all subjects had made their choice, they received information about their choice, their opponent's choice, their own earnings for that round and their total accumulated earnings.

At the end of the session a debriefing questionnaire was administered. Then, subjects were paid in cash based on their accumulated total earnings for all 20 rounds, using the exchange rate £1 = \$4. Each session lasted less than an hour and participants averaged earnings of £8.47 (£6.70 in SYMLOW, £8.31 in ASYM and £10.40 in SYMHIGH)⁹.

3. Experimental results

Overview. We start with the overall results in the random pairing treatments. Table 2 shows the predicted and average actual payoffs for the jurisdictions. The second column reports the predicted Nash and cooperative outcomes, while the last column depicts the actual payoffs as observed in the laboratory. It is clear to see our experimental data conforms to the theory in that it closely mirrors the Nash outcomes as opposed to the efficient choices.

**** TABLE 2 ABOUT HERE ****

**** TABLE 3 ABOUT HERE ****

Table 3 provides the proportion of Nash choices in the two treatments showing data respectively for: the first and last round (rounds 1 & 20 respectively); in 4 different quarters; first ten and last ten rounds; all 20 rounds aggregated. Overall, correspondingly 39.6%, 41.3% and 62.5% of choices in SYMLOW, ASYM and SYMHIGH are equilibrium decisions. Equilibrium options appear to increase over time. Nash tax choices are significantly less in the first five rounds but by the last five rounds there are substantial equilibrium choices. This

⁸ In the experiment for simplicity we labelled our tax options as {1, 2, 3, 4}.

⁹ Average hourly earnings in the experiment were much higher than the shadow wage of a student.

is consistent with previous studies on non-cooperative social dilemmas (see Andreoni, 1988 or Cooper et al. 1996).

Treatment Effects. To examine the existence of any significant differences between SYMLOW and ASYM and SYMLOW and SYMHIGH, we used logistic panel regressions. We have *best reply action* as dependent variable and we investigate the effect of a number of independent variables. Our first specification contains four explanatory variables. The treatment variables *ASYM* and *SYMHIGH* are dummy variables that take value one if the observation was collected in the asymmetric and symmetric with high payoffs treatments and zero otherwise (meaning we use observations from symmetric with low payoff game as a benchmark). The *Role* dummy measures whether we have a ‘disadvantaged’ (column) or an ‘advantaged’ (row) player and is equal to one if we have a ‘disadvantaged’ player. In addition, we use the variable *Round* to control for the effect of time on choices. A second specification controls for time included as an interaction with the treatment variables as *ASYMxRound* and *SYMHIGHxRound*. The estimated two regressions which use the full sample are reported in Table 4.

**** TABLE 4 ABOUT HERE ****

Focussing on columns (1) and (2), we can see that the first specification has a better fit (Model χ^2 is higher). The treatment variable *ASYM* is insignificant in the first regression, while *SYMHIGH* appear significant and positive. With respect to the SYMLOW and ASYM comparison this is hardly surprising as Nash proportions are roughly the same, which a Fisher’s exact test confirms (p-value = 0.39 in Table 3).

The positive significant coefficient on *SYMHIGH* indicates it is more likely for policymakers to choose their best strategies when payoffs are symmetrically higher. As Table 3 reveals Nash proportion is about 62.5% in SYMHIGH compared to 39.6% in SYMLOW. Again the Fisher’s exact test reports a p-value of 0. The main difference between these two games is the symmetrically higher payoffs in SYMHIGH relative to SYMLOW. Thus, this is indicative that payoff size effect matters in that it leads play closer to equilibrium play.

This result echoes previous findings in the experimental literature that have shown that monetary incentives do reduce variation and improve performance in certain contexts (see Smtih, 1962; Camerer and Hogarth, 1999). In a recent experimental study involving voting, Bassi, Morton and Williams (2006) find that financial incentives can raise the likelihood that subjects make decisions closer to equilibrium prediction, which lead the authors to conclude that higher monetary rewards induce subjects to devote more cognitive attention to tasks. In our case we emerge with the result that because governments have more to lose when payoffs are higher, they more likely to undercut each other in taxes.

The variable *role* has a significant positive influence on choices which is indicative that the disadvantaged (column) player is more likely to choose the best strategy. As an initial take on this result, this seems to fit with the pre-asserted belief that the underprivileged player is sufficiently likely to be more competitive as opposed to the privileged player.

The regression in column (1) indicates that equilibrium decisions increase considerably over time. Furthermore, in the next column we report our result on the test whether the asymmetric and the higher symmetric games reveal anything different over time compared to the baseline symmetric treatment (*ASYMxRound* and *SYMHIGHxRound*). Only *ASYMxRound* is significant suggestive that the differences in choices between benchmark symmetric and asymmetric games can be time variant.

Our results so far are conclusive about the underprivileged (column) player selecting the best strategy more often. In fact the first two regressions in Table 4 support our claim. The coefficients on the variable *role* are significant.

To investigate if we can detect any difference in the three games we ran our panel regressions separating our data for the three treatments treating them as three sub-samples. Three separate regressions that include *role* and the time variable *Round* are reported in columns (3)-(5) in Table 4.

Comparing the three specifications, we find that the variable *role* is insignificant in the SYMLOW game, while it is only significant at a 5% level in the symmetric game with higher payoffs. The significance and magnitude in the asymmetric game is starker. This indicates the

advantaged player is less likely compared to the disadvantaged player to choose the best reply action. These highlighted differences in behaviour between players, further highlights differences across how choices are made in the three games.

The differences. To further investigate the differences we depict the proportion of selective and most frequent action combinations and strategies in the three treatments in Table 5. It is clear from the table that the most common pair of strategies is the equilibrium ones in all three treatments. In contrast tax cooperation is insignificant with the tax pair (1,1) chosen 1.3%, 0% and 1.3% in correspondingly SYMLOW, ASYM, and SYMHIGH. In SYMLOW, the next most frequent outcomes were choices close to the equilibrium tax option (i.e strategies (0.5,0.667) and (0.667,0.5)). The individual decisions are further revealing in that both players chose their best tax strategies 60% of the time. In SYMHIGH the next most selected tax pair is (1,0.667). Individually, the column player's best reply choice amounts to 87.5% of that player's choice as opposed to the 71.7% chosen by the row player. However, it is ASYM that depicts the most interesting story. While the Nash outcome is prevalent 41.3% of the time in decisions made, the strategy pair (0.667,0.548) is also significantly chosen. In effect though the 'disadvantaged' (column) player chose the non-cooperative tax option extensively (81.7%), the 'advantaged' (row) player also opted for the higher tax option 0.548 (45.4%). The tax pair (0.667, 0.548) is the next best outcome in ASYM (34.6%).

One possible explanation for this behaviour on the part of the advantaged decision maker can be given in terms of the initial uncertain beliefs of these types of decision makers. The uncertainty prevailing is the naive view the advantaged players may have about the disadvantaged player. If they believe that the latter is equally likely to choose any tax option, then working out their own expected payoffs for the four strategies gives an expected payoff of 2.18 for the higher tax option 0.667 compared to the lower expected payoff of 2.13 for tax option 0.613. This belief however is gradually eroded over time as they realise that their opponent is choosing the non-cooperative tax option and thus as Table 3 reveals Nash choices (in ASYM) increases significantly after the first ten rounds (changes from 28.3% to 54.2%).

One striking observation is the behaviour of the disadvantaged decision maker. This player chooses the best strategy 81.7% of the time. This is line with previous studies on asymmetric games that disadvantaged players tend to be uncooperative and compete fiercely (see Beckenkamp et al.). This is explained through existing inequality in the distribution of payoffs where the player receives the lower payoff and is thus more likely to behave uncooperatively.

To summarise, most choices seem consistent with the Nash prediction and conformance between our data and theoretical prediction improves as a session progresses. However, we also detect a considerable amount of differences when we compare the ASYM and SYMHIGH to SYMLOW. We have detected a payoff size effect (SYMLOW v. SYMHIGH). In addition, while on the aggregate there is no difference in behaviour between SYMLOW and ASYM, further analysis point to two major differences pertaining to behaviour. First, differences in choices across the two treatments are time variant. Secondly, we detect a payoff advantage effect when comparing SYMLOW to ASYM. Furthermore, some of these differences appear even in the later periods. For instance, even in the last five rounds behaviour across the games differ with respect to choosing the equilibrium taxes (see Table 5). While choices are mostly equilibrium ones in SYMHIGH, non-equilibrium behaviour is still prevalent in SYMLOW and ASYM.

Repeated Interactions. Our results so far allow us to conclude that there are certain differences between the symmetric benchmark tax competition game and the two other games. To provide further insights and possibly reinforce our claim we stress test our findings by subjecting the games to a study under repeated interactions.

**** TABLE 6 ABOUT HERE ****

Table 6 portrays the aggregated choices in the two games under repeated interactions. The only similarity between SYMLOWFIXED and ASYMFIXED are the roughly similar Nash choices (Fisher's Test, p -value = 0.363 on the aggregate). The main difference in these two games is the choice proportion for the efficient outcome. In SYMLOWFIXED, 17 out of

80 games played resulted in reciprocal cooperation (21.3%). However, behaviour in ASYMFIXED was purely self-interested as the cooperative outcome was chosen 1 out of 80 times (1.3%). Comparing SYMLOWFIXED and SYMHIGHFIXED reveals differences only at the 10% significance level with Nash choices compared as 26.3% to 15% and efficient outcomes as 21.3% to 32.5%. However, these differences emerge as a result of differences in the first ten rounds. In latter periods differences between SYMLOWFIXED and SYMHIGHFIXED disappear. In effect choices in SYMLOWFIXED and SYMHIGHFIXED are comparatively similar in the last ten rounds. For the Nash choices we have 23% v. 20% and for the efficient choices we have 35% v. 30%.

Our results seem to show that tax cooperation can develop in the two symmetric games but fails to emerge in the asymmetric one. This fits in line with the predictions by Cardarelli et al. (2002). The main result from their repeated tax competition model is that tax cooperation can be sustained if countries have symmetric valuation for the public good and are patient enough. However, this would not prevail if countries are asymmetric and the difference in preferences for the public good is large.

Another interesting result from our comparison of SYMLOWFIXED and SYMHIGHFIXED is efficient outcome overall is significantly higher in the latter treatment (Fisher's test of difference reports a p-value of 0.08). This implies tax policy cooperation can be sustained if gains from cooperation are symmetrically higher.

A cursory comparison of our results under random pairing compared to fixed reveals that choices under repeated pairing is much lower. This fits with previous literature that find with random matching choices tend to approximate equilibrium choices far more (Huck, 2004).

So similar to our previous findings we can report that, while we observe some similarities in the symmetric tax competition games, we can also observe significant differences in behaviour when we have asymmetry.

4. Conclusion

This paper reports results of an experiment designed to investigate the impact of a payoff advantage, symmetric payoff change and policymakers interaction on choices in tax competition games. Our results show differences when a symmetric tax competition game with low payoffs is compared to an asymmetric game with payoff advantage and symmetric game with symmetrically higher payoffs. The comparison between the two symmetric games reveals the existence of a payoff size effect where behaviour moves closer equilibrium decision making. Instead, while on the aggregate overall choices in the symmetric and asymmetric games does not appear different, our investigation points to two important treatment effects. First, differences in choices are time variant with equilibrium choices chosen frequently more over time in the asymmetric setup. Secondly, play by policymakers individually conveys a picture of significant differences in behaviour. We find that the advantaged as opposed to the disadvantaged decision maker choose to tax consistently over the best tax choice and the underprivileged policymaker behaves more competitively, choosing his/her best strategy unflinchingly.

We then compared the three games when policymakers repeatedly interacted. We find that the players' behaviour also differed. While there was some reciprocal cooperation in the symmetric tax competition games, the decision makers hardly ever cooperated in the asymmetric setting. This fits with the repeated tax competition model of Cardarelli et al. who opine that asymmetries reduce tax cooperation, making it unsustainable.

Our findings highlight the importance of asymmetry in the study of the tax competition-coordination debate. There is an ongoing debate as to whether international taxes on capital should be coordinated or not. The existence of tax competition between nation states and its resulting inefficient outcome, as postulated by theory, is an often cited reason to make a case for coordination. For instance, giving credence to the inefficiency result, the European Union has been campaigning for coordinated tax setting to ensure that tax competition does not undermine the tax revenue of European countries derived from taxed capital income (Zodrow, 2003). However, most of the theoretical studies in this literature which study this debate apply

a symmetric setup. Thus, most theoretical predictions produced ignore the salient features of asymmetry and how hard coordination is. While a symmetric setup is a good starting point, our study suggests the use of an asymmetric setup as an important facet to better understand this debate.

Table 1. Jurisdictions payoff matrices

Case I: $\gamma_A = \gamma_B = 2$				
	0.4	0.5	0.667	1
0.4	1.10,1.10	1.20,1.20	1.30,1.00	1.70,0.60
0.5	1.20,1.20	1.30,1.30	1.50,1.20	1.80,0.80
0.667	1.00,1.30	1.20,1.50	1.40,1.40	1.90,1.10
1	0.60,1.70	0.80,1.80	1.10,1.90	1.70,1.70

Case II: $\gamma_A = 3$ and $\gamma_B = 2$				
	0.548	0.613	0.667	1
0.548	1.80,1.30	1.90,1.20	2.00,1.20	2.60,0.80
0.613	1.90,1.40	1.90,1.30	2.00,1.30	2.70,1.00
0.667	1.80,1.50	2.00,1.40	2.10,1.40	2.80,1.10
1	1.40,1.80	1.60,1.80	1.70,1.90	2.70,1.70

Case III: $\gamma_A = \gamma_B = 3$				
	0.4	0.5	0.667	1
0.4	1.50,1.50	1.60,1.70	1.80,1.50	2.30,1.00
0.5	1.70,1.60	1.70,1.70	2.00,1.80	2.50,1.30
0.667	1.50,1.80	1.80,2.00	2.10,2.10	2.80,1.70
1	1.00,2.30	1.30,2.50	1.70,2.80	2.70,2.70

Table 2. Jurisdictions payoff levels

	Predicted		Actual
	<i>Nash</i>	<i>Efficient</i>	
<u>SYMLOW:</u>			
<i>Jurisdiction A</i>	1.30	1.70	1.33
<i>Jurisdiction B</i>	1.30	1.70	1.34
<u>ASYM:</u>			
<i>Jurisdiction A</i>	1.90	2.70	1.89
<i>Jurisdiction B</i>	1.40	1.70	1.44
<u>SYMHIGH:</u>			
<i>Jurisdiction A</i>	2.10	2.70	2.06
<i>Jurisdiction B</i>	2.10	2.70	2.08

Table 3. Proportion of Nash Choices

<i>Treatments</i>	<i>Rounds</i>								
	<i>1</i>	<i>20</i>	<i>1-5</i>	<i>6-10</i>	<i>11-15</i>	<i>16-20</i>	<i>1-10</i>	<i>11-20</i>	<i>1-20</i>
SYMLOW	0.167	0.583	0.20	0.45	0.433	0.500	0.325	0.467	0.396
ASYM	0.167	0.333	0.167	0.40	0.517	0.567	0.283	0.542	0.413
SYMHIGH	0.333	0.583	0.467	0.583	0.65	0.80	0.525	0.725	0.625
<i>Fisher's Exact Test p-value</i>									
<i>(SYMLOW vs ASYM)</i>	0.705	0.207	0.407	0.356	0.232	0.292	0.287	0.151	0.390
<i>(SYMLOW vs SYMHIGH)</i>	0.320	0.660	0.001	0.100	0.014	0.001	0.000	0.000	0.000

Table 4. Random effects Logit regressions results

	<i>Dependent variable: Best reply action</i>				
	<i>Full sample</i>	<i>Full Sample</i>	<i>Sub-samples</i>		
	<i>(1)</i>	<i>(2)</i>	<i>SYMLOW only (3)</i>	<i>ASYM only (4)</i>	<i>SYMHIGH only (5)</i>
<i>Constant</i>	-1.14** (0.44)	-0.66** (0.34)	-0.39 (0.60)	-1.99*** (0.51)	-0.38 (0.51)
<i>ASYM</i>	0.13 (0.51)	-	-	-	-
<i>SYMHIGH</i>	1.36*** (0.53)	-	-	-	-
<i>Role</i>	1.21*** (0.43)	1.24*** (0.53)	0.02 (0.80)	2.31*** (0.63)	1.34** (0.68)
<i>Round</i>	0.12*** (0.01)	0.10*** (0.02)	0.11*** (0.02)	0.17*** (0.02)	0.09*** (0.02)
<i>ASYM x Round</i>	-	0.05* (0.03)	-	-	-
<i>SYMHIGH x Round</i>	-	0.02 (0.03)	-	-	-
No. of Obs.	960	960	480	480	480
Log-likelihood	-672.65	-674.97	-240.55	-222.26	-203.14
Model χ^2	96.83***	92.17***	24.97***	55.05***	18.15***

Standard errors in parentheses.

*, **, *** indicate significance at the 10%, 5% and 1% levels respectively

Table 5. Proportion of select and most frequent action combinations and strategies

SYMLOW			ASYM			SYMHIGH		
Action pair	Proportion		Action pair	Proportion		Action pair	Proportion	
(0.5,0.5)	0.396		(0.613,0.548)	0.413		(0.667,0.667)	0.625	
(0.5,0.667)	0.154		(0.667,0.548)	0.346		(1,0.667)	0.121	
(0.667,0.5)	0.133		(0.667,0.667)	0.075		(0.4,0.667)	0.100	
(1,1)	0.013		(1,1)	0.000		(1,1)	0.013	

SYMLOW			ASYM			SYMHIGH		
Player	Strategy	Proportion	Player	Strategy	Proportion	Player	Strategy	Proportion
Row	0.5	0.596	Row	0.613	0.479	Row	0.667	0.717
	0.667	0.271		0.548	0.454		1	0.138
Column	0.5	0.617	Column	0.548	0.817	Column	0.667	0.875
	0.667	0.238		0.667	0.138		1	0.096

SYMLOW			ASYM			SYMHIGH		
Action pair	Proportion		Action pair	Proportion		Action pair	Proportion	
(0.5,0.5)	0.500		(0.613,0.548)	0.567		(0.667,0.667)	0.800	
(0.5,0.667)	0.200		(0.667,0.548)	0.283		(1,0.667)	0.005	
(0.667,0.5)	0.150		(0.667,0.667)	0.083		(0.4,0.667)	0.005	
(1,1)	0.000		(1,1)	0.000		(1,1)	0.000	

Table 6. Differences under repeated interactions

Treatments	Rounds					
	Nash Choices proportion			Efficient Choices proportion		
	1-10	11-20	1-20	1-10	11-20	1-20
SYMLOWFIXED	0.300	0.230	0.263	0.075	0.350	0.213
ASYMFIXED	0.175	0.425	0.300	0.025	0.000	0.013
SYMHIGHFIXED	0.100	0.200	0.150	0.350	0.300	0.325

	Fisher's Exact Test p-value					
(SYMLOWFIXED vs ASYMFIXED)	0.147	0.047	0.363	0.308	0.000	0.000
(SYMLOWFIXED vs SYMHIGHFIXED)	0.024	0.547	0.058	0.003	0.406	0.080

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Appendix A: Equilibrium Tax Rates {not for publication}

Solving for the equilibrium tax rates involves the following steps. As a first step we need to find equations for $k(t)$ and $r(t)$ which can then be used to get an expression for private consumption solely in terms of tax rates, $C(t)$. Similarly using $k(t)$ into the public good function should yield $G(t)$. Then using the expressions $C(t)$ and $G(t)$ provides an expression for utility of the representative citizen only as a function of t , $U(t)$. Then, maximise this function subject to taxes. This exercise is carried out for jurisdiction i .

Through a process of substituting for $f'(k)$ and \bar{k} as defined by equations (4) and (5) in equation (6), the expression for the net return on capital r , arrive at

$$k_i = 1 - t_i + t_j \quad \frac{\partial k_i}{\partial t_i} < 0, \quad \frac{\partial k_i}{\partial t_j} > 0$$

for jurisdiction i . This expression defines $k(t)$.

To find $C(t)$, the expression for private consumption, plug the equation of the capital employed as a function of tax rates, $k(t)$, into $f(k_i)$, $f'(k_i)$, r which should leave us with

$$C_i = \frac{3}{4} - t_i - \frac{1}{2}t_i t_j + \frac{1}{4}t_i^2 + \frac{1}{4}t_j^2$$

Next, make use of $k(t)$ into the equation for the public consumption, (7), to yield

$$G_i = t_i - t_i^2 + t_i \cdot t_j$$

Then, combining $C(t)$ and $G(t)$ can produce the following utility function

$$U[C_i(t), G_i(t)] = \frac{3}{4} + (\gamma_i - 1)t_i + (\gamma_i - \frac{1}{2})t_i t_j - (\gamma_i - \frac{1}{4})t_i^2 + \frac{1}{4}t_j^2$$

The objective of each jurisdiction is to solve for $t^* = \arg \max_t U(t)$ which requires

setting $\frac{\partial U_i(\cdot)}{\partial t_i} = 0$. This yields the best response function for jurisdiction i

$$t_i = \left(\frac{\gamma_i - 1}{2\gamma_i - \frac{1}{2}} \right) + \left(\frac{\gamma_i - \frac{1}{2}}{2\gamma_i - \frac{1}{2}} \right) \cdot t_j \quad ; t_i \geq \frac{\gamma_i - 1}{2\gamma_i - \frac{1}{2}}, \gamma_i > 1$$

which can be used in conjunction with jurisdiction j 's best response function to solve for the equilibrium tax rate

$$t_i^* = \frac{3\gamma_i\gamma_j - \frac{3}{2}\gamma_i - \frac{5}{2}\gamma_j + 1}{3\gamma_i\gamma_j - \frac{1}{2}\gamma_i - \frac{1}{2}\gamma_j}$$

Two interesting properties worth noting are the existence and uniqueness of equilibrium. The second-order condition can be solved as

$$\frac{\partial^2 U_i(\cdot)}{\partial t_i^2} = -(2\gamma_i - \frac{1}{2}) < 0 \text{ for } \gamma_i > 1$$

revealing it holds. With respect to the uniqueness of equilibrium rates one can draw from the fact that the reaction functions are both continuous and strictly linearly increasing in the other jurisdiction's tax rate and hence establish the premise for single crossing, which imply uniqueness.

Appendix B: Inefficient tax competition {not for publication}

The proposition of inefficient tax competition can be stated as follows,

Proposition. *Tax competition leads jurisdictions to set an inefficiently low source-based capital tax rate in equilibrium, relative to the coordinated tax rate.*

Proof. Differentiating the utility of the representative consumer in jurisdiction i

$$U[C_i(t), G_i(t)] = \frac{3}{4} + (\gamma_i - 1)t_i + (\gamma_i - \frac{1}{2})t_i t_j - (\gamma_i - \frac{1}{4})t_i^2 + \frac{1}{4}t_j^2$$

gives

$$dU(t_i, t_j) = (\gamma_i - 1)dt_i + (\gamma_i - \frac{1}{2})dt_i t_j - (2\gamma_i - \frac{1}{2})dt_i t_i$$

For the symmetric case $\gamma_i = \gamma_j$ we have $t_i = t_j$ which reduces the above equation to

$$dU(.) = \gamma_i dt_i (1 - t_i) - dt_i$$

Simplify this equation under three cases: when symmetric jurisdictions set equilibrium taxes $t_i = t_i^*$; given $\gamma_i > \gamma_j$ asymmetric jurisdictions set taxes non-cooperatively $t_i > t_j$; regions prefer to cooperate over taxes $t_i = t_j = 1$.

Plugging for the equilibrium tax rates $t_i = t_i^* < 1$ we have

$$dU(.)|_{\text{Sym}} = \gamma_i dt_i (1 - t_i^*) - dt_i$$

Alternatively for the asymmetric case $\gamma_i > \gamma_j$ we have $t_i > t_j$ which can be re-defined as $t_j = t_i - \Delta$, where $0 < \Delta < 1$, which imply an alternative expression in the asymmetric case

$$dU(.)|_{\text{Asym}} = \gamma_i dt_i (1 - t_i^* - \Delta) - (1 - \frac{1}{2}\Delta) dt_i$$

Finally, if jurisdictions set taxes cooperatively, such that $t_i = t_j = 1$, the equation can be rewritten as

$$dU(.)|_{\text{Coop}} = -dt_i$$

How to tell that the pair of Nash tax rates (t_i^*, t_j^*) are inefficiently low? Observe that if tax rates are set below unity then for any pair of Nash tax rates less than unity a comparison of equations $dU(.)|_{\text{Sym}}$ and $dU(.)|_{\text{Asym}}$ to equation $dU(.)|_{\text{Coop}}$ reveals that both jurisdictions can raise welfare if they set tax rates cooperatively at unity above the equilibrium tax rate, t_i^* .

Given the first term in both $dU(.)|_{\text{Sym}}$ and $dU(.)|_{\text{Asym}}$ are positive it shows the unexploited gains from coordination when taxes are set below unity. Then what remains in $dU(.)|_{\text{Coop}}$ is the temptation payoff for undercutting the other jurisdiction.

This in turn means if regions set tax rates non-cooperatively below unity they should be inefficiently low as there is a potential gain in welfare from raising tax rates simultaneously. The intuition behind this proposition can be explained by the fact that a decrease in the tax rate in one of the jurisdictions will be met by a reduction in the tax rate of the other region in an attempt to influence the destination of capital by influencing the return on capital. This is because if a tax cutting is not met by a reduction in taxes then capital will fly from one region to another ■

Appendix C: Sample Instructions {not for publication}

Instructions

Welcome to the experiment. Please read and follow the instructions carefully. A good understanding of the task you will be asked to perform will increase your chances of earning some money. During the experiment your earnings will be given in dollars, which will be converted into pounds at the end of the experiment at a rate of £1=\$4. This money will be paid in cash and in private at the end of the session. Please do not talk or communicate with the other participants in this room during the session. If you have any questions just raise your hand and I will come to where you are seated to answer any query that you may have. Please do not touch the computer until the experiment starts.

Introduction

This is an experiment on decision making. There are 8 people in this room who are participating in this experiment. The experiment consists of 20 rounds. In each round of this session, the computer will randomly pair you with someone else in the room. However, you will not learn which of the people in the room you are paired with. How much you earn during the session depends on your decisions and those of the people you are paired with, during these 20 rounds.

What you have to do?

In the experiment you will play the role of either a ‘row’ player or a ‘column’ player. [**You will be a row player in all rounds**]. You will face the payoff matrix on the next page for the 20 rounds. The payoff matrix has 4 rows and 4 columns. Since there are four possible options for each player, there are sixteen possible combinations or ‘cells’ in the table. The numbers shown in those 16 cells are simply the payoffs, with two numbers reported for each cell. The row player's options and payoffs are shown in **blue** in the left corner and the column player's options and payoffs are shown in **red** on the top. The intersection of the row selected by one person and the column selected by the other will determine the earnings for each person.

Here is an example on how to read the payoff matrix. If the row player chooses **1** and the column player chooses **3** the payoff shown is **\$1.30,\$1.00**: the row player gets a payoff of **\$1.30**, the column player gets **\$1.00**.

For each round, the row player will choose one of the rows from the left corner and the column player will choose one of the columns on the top of the payoff matrix. This means in each round you have to choose between the four possible options labelled as: 1, 2, 3, and 4. You make your decision on your computer by choosing one of these 4 numbers, using the computer mouse. At the end of each round, after taking your decision, you will be prompted to confirm or change your decision. Once you confirm your decision, you will either get a screen telling you to wait, if the other person's decision has not yet been received, and that you can use the ‘check to see if others have finished’ button. Otherwise, your choice and the choice of the other player will be displayed. Your terminal will also display your earnings for that round and your accumulated total earnings from all rounds. At the beginning of each round, along with telling you the round number, the computer will display a history for each round, showing your decision you had taken, the other person's decision, your earnings and total earnings, with the most recent round shown first.

Payoff Matrix (Row, Column)

	1	2	3	4
1	\$1.10,\$1.10	\$1.20,\$1.20	\$1.30,\$1.00	\$1.70,\$0.60
2	\$1.20,\$1.20	\$1.30,\$1.30	\$1.50,\$1.20	\$1.80,\$0.80
3	\$1.00,\$1.30	\$1.20,\$1.50	\$1.40,\$1.40	\$1.90,\$1.10
4	\$0.60,\$1.70	\$0.80,\$1.80	\$1.10,\$1.90	\$1.70,\$1.70