A Race beyond the Bottom: The Nature of Bidding for a Firm

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Abstract

We examine how the bidding environment may affect the outcome of tax competition between two countries (or two regions) in attracting a firm's foreign direct investment (FDI).We compare the equilibrium location choice and payoffs from an English auction, with both complete and incomplete information, relative to those in the traditional setting of a sealed-bid first-price auction. We find that an English auction leads to more aggressive bidding in "race *beyond* the bottom," where the nations may bid beyond their own valuations of the FDI. We also discuss the roles of auction protocol and information asymmetry on the auction outcome.

JEL-Code: F12, F23, H25, H73.

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1 Introduction

It has been well documented that countries, states, or municipalities bid for firms by giving generous tax incentives, investing in infrastructure, providing worker education opportunities or offering other benefits to the companies. The state of Georgia, for example, offered $320 million incentives to win a bidding war for DaimlerChrysler's assembly plant over South Carolina that had offered as much as $346 million in incentives to try to lure the factory (*New York Times*, October 18, 2002). Despite The Philippines having made a generous offer to General Motors (GM), including free use of land and tax and tariff cuts, Thailand succeeded in luring GM's Asian motor-vehicle manufacturing base by waiving its domestic content requirements for the entire industry (*Financial Post*, May 30, 1996).[1] The empirical relevance of bidding wars for firms is confirmed by Greenstone and Moretti (2004) and Devereux, Lockwood, and Redoano (2008) among others.

Tax competition among regions for attracting capital was first analyzed formally by Wilson (1986) and Zodrow and Mieszkowski (1986).[2] Black and Hoyt (1989) analyze bidding competition for lumpy investment (or large firms), which has been followed by a now well established literature on international competition for foreign direct investment (FDI) (e.g., Haaparanta, 1996; Haaland and Wooton, 1999; Haufler and Wooton, 1999; Fumagalli, 2003; Olsen and Osmundsen, 2003; Bjorvatn and Eckel, 2006; and Ferrett and Wooton, 2010).

One of the most important results in the literature of tax competition is the phenomenon known as the "race to the bottom." With identical potential host nations bidding to attract the firm, each country is prepared to undercut its rival's offer such that, in equilibrium, all of the winner's gains from the FDI are transferred to the firm. Thus the host country fares no better than the losing country, despite receiving the investment. Haufler and Wooton (1999), however, show that this "race to the bottom" outcome changes when one nation is larger than the other. A size asymmetry will result in the larger country winning the bidding contest, as it is both more attractive to the investor and is prepared to pay a larger subsidy

[1] Davies (2005) lists various automotive plant incentive packages in Table 1 of his paper.

[2] See Wilson (1999), Wilson and Wildasin (2004), and Dembour (2008) for literature survey of tax competition.

(or offer lower corporate taxation) in order to lure the FDI. Despite the larger country's greater willingness to pay to attract the FDI, it need only slightly improve upon the offer made by the rival, smaller country and thereby captures for itself some of the benefits of the FDI.

One interesting and important extension of the basic tax competition structure is to accommodate uncertainty regarding the firm's local productivity or the benefits that regions obtain from attracting the firm. Black and Hoyt (1989) and King, McAfee, and Welling (1993) examine the bidding for firms under incomplete information about the firm's local productivity.[3] They demonstrate that the existence of uncertainty may cause overbidding and inefficient location of firms. Beyond this, Bond and Samuelson (1986) show that, under incomplete information, tax holidays work as a signal for local productivity.[4]

Ferrett and Wooton (2010) use the same framework as Haufler and Wooton (1999) to explore another interesting direction of research. They investigate whether the assumption that the firm is owned entirely by individuals who do not live in either bidding country has an impact on the outcome of the competition. This is an important question as most large firms in this globalized world are owned by shareholders who are geographically dispersed. As an example, in December 2008, 44.2% of the shares of a Japanese electronics company, Canon, were held by foreign citizens. Similarly, the ratio of foreign shareholders in Sony was 50.1% in March 2006. Thus, the impact of firms' share-distribution on the results of tax competition is of practical importance. Intuitively, a country would be expected to bid more aggressively (offering bigger subsidies to the firm) if its citizens own a large share of the firm, as much of the cost of the bid is merely a transfer from the government of the country to these citizens. However, Ferrett and Wooton (2010) establish an "invariance result" showing that the unique equilibrium of a tax/subsidy competition game between the two governments is independent of how the firm's ownership is distributed internationally. Their result applies both to the equilibrium location of the firm's plant and to the countries'

[3]See also Scoones and Wen (2001).

[4]Kaplan, Luski, and Wettstein (2003) extend Bond and Samuelson's (1986) model to allow regions to give grants to the firm in addition to lowering the tax rate.

equilibrium tax/subsidy offers. Thus the nationality of the firm is irrelevant to the strategy that a potential host country should follow in offering investment incentives. This conclusion is quite significant for the policymaker who can ignore the ownership of the firm. Indeed, the policymaker need never know who the firm belongs to.

This "invariance result" can be understood with an example. Consider a situation in which Germany and France compete for a firm. Suppose that the two nations are equally attractive to the firm as hosts, so that the firm will choose the country that offers the better bid. we further assume that German shareholders hold 30% and French shareholders hold 20% of the firm's shares. Let France offer €100 million incentives to the firm while Germany improves slightly upon this offer and wins. In doing so, German shareholders have lost €30 million, their share of the French offer had it been successful. But at the same time, these German shareholder receive (approximately) €30 million out of (approximately) €100 million paid by their own government. Similarly, French shareholders get €20 million regardless of which country wins. Thus, on balance, the shareholders are unaffected by whichever country's bid is successful in attracting the FDI. So the fact that Germany (or the winner of the auction) owns part of the firm would not change the outcome of the tax competition.

This argument, however, depends critically on the protocol of tax competition. As with Haufler and Wooton (1999), Ferrett and Wooton (2010) treat the bidding contest as a simultaneous bidding (or sealed-bid first-price auction) under complete information. What is critical for such *simultaneous* bidding is that raising a bid cannot induce its rival country to follow suit and increase its offer. But, in reality, regions often counter each others' bids with a better offer. In a fierce bidding war for Toyota's assembly plant among the Canadian provinces of Ontario, British Columbia and Quebec it was reported that "Quebec promises to match the other two provinces" in offering investment incentives (*Financial Post*, August 3, 1985). Similarly in the US, Hyundai continued negotiations with the Commonwealth of Kentucky about $1 billion auto assembly plant until only hours before the announcement that the firm had picked the State of Alabama as the winner of the bidding (*Site Selection*,

May 2002).

In this paper, we examine the impact of changing the contest from the sealed-bid auction of the previous literature to a (perhaps) more-realistic, English auction (or ascending-price auction), where the contestants react sequentially to their rivals' offers. In such auctions, increasing a bid would be very likely to induce its rival country (or countries) to counter the improved bid. In many situtations, inducing its rival to bid higher does not bring any benefits to a losing country. But it matters significantly if the losing country owns part of the firm, as its citizens capture part of the winner's bid. Thus the losing country has an incentive to raise its bid to induce the other country to follow suit. Indeed, the greater the shares that its citizens own, the greater is the incentive to bid more aggressively.[5] Tax competition in the form of English auction has been considered in the literature (e.g., King, McAfee, and Welling, 1993) as an equivalent to the second-price auction. In the existence of an externality such as the loser benefitting from an increase in the winning bid, the English auction should not be simply considered the same as the second-price auction. This paper is the first to examine the use of an English auction for the FDI when citizens of bidding countries own part of the firm.

In section 3, we revisit simultaneous bidding under complete information as a benchmark, and confirm that Ferrett and Wooton's (2010) invariance result holds and that the winning bid equals the losing country's valuation of the FDI in the undominated Nash equilibrium. This result, however, is not robust to a change in the auction protocol. We show in section 4 that, if the citizens of a losing country own some shares of the firm, the equilibrium winning bid equals the winner's valuation of the FDI in the English auction. Thus the "race to the bottom" re-emerges even though the valuations are different between two countries. When its citizens own some shares of the firm, the losing country has an incentive to push up the bids such that the equilibrium bid matches the winner's valuation of the FDI.

We then investigate the role of information in bidding strategies and the resulting equi-

[5]Interestingly, what matters in the English auction is the share of the firm that the residents of the losing country own. In our previous example, it is French share of 20% (but not German share of 30%) that would affect the auction outcome.

librium bid. In section 5, we find that each country's bid is smaller than its own valuation of the FDI in simultaneous bidding under incomplete information regarding the other country's valuation. The resulting winning bid may be smaller or greater than the losing country's valuation. Each country's bid increases with its citizens' share of the firm, so Ferrett and Wooton's (2010) invariance result once again does not hold in the presence of incomplete information. More importantly, the fact that its citizens own a fraction of the firm induces a country to bid more aggressively because the citizens re-capture this fraction of the own bid.[6] This reason for aggressive bidding contrasts sharply with that in the English auction, in which only the losing country bids aggressively to raise the winning bid, so that its citizens obtain higher dividends from the firm.

Finally in section 7, we derive equilibrium of the English auction for FDI under incomplete information. We show that each country is prepared to bid *beyond* its valuation if its citizens own some shares of the firm. As a consequence, a "race beyond the bottom," such that a country may lose by winning the auction, can result. An inefficient allocation may also occur, in that the firm locates in the country with the lower valuation of the FDI.

2 The model

There are two countries, A and B, bidding to attract the investment of a single firm. The government of country i $(i = A, B)$ makes an offer of b_i to the firm in order to attract its investment. When $b_i > 0$ the country is prepared to subsidize the investment, while $b_i < 0$ is a tax on the firm. We make the simplification that, in the absence of these transfers, the firm is indifferent between the two potential host locations as its profits are identical and equal to π from producing in either country.[7] After the governments make their bids, the monopolist decides where to locate its plant while the product markets in countries A and B are served in the final stage.

[6] It is easy to see that if its residents own 100% of the firm, bidding for the FDI is virtually costless for the country.

[7] Thus there is no "geographic advantage" to the firm locating in one market relative to the other. We make this assumption simply to reduce the notational complexity. Our results would be qualitatively unchanged if, for example, pre-tax profits were higher in country A (as is assumed by Ferrett and Wooton, 2010).

The benefit to country i of having local investment is assumed to be S_{ii}, while it gets S_{ij} $(i \neq j)$ when the firm produces in country j and services its market through international trade. We assume that local investment is always preferred to imports and hence $S_i \equiv S_{ii} - S_{ij}$, country i's *valuation* of the FDI, is always positive.[8] We assume, without loss of generality, that $S_A \geq S_B > 0$ in the case where countries' valuations are common knowledge. Thus country A values the investment at least as much as country B does.

In addition to the benefits of the FDI to the nation as a whole, country i's citizens are assumed to own a fraction e_i of the investing firm and consequently receive that share of the firm's after-tax profits. We write W_{ij} for country i's overall welfare benefit payoff from the firm locating in country j. Then, country i's welfare, dependent upon the location of the investment, is given by

$$W_{ii} = e_i(\pi + b_i) - b_i + S_{ii}, \tag{1}$$

$$W_{ij} = e_i(\pi + b_j) + S_{ij}, \ i \neq j. \tag{2}$$

Let the net welfare benefit of hosting the firm be $W_i \equiv W_{ii} - W_{ij}$. Thus country i strictly prefers hosting the firm if and only if

$$W_i = e_i(b_i - b_j) - b_i + S_i > 0, \tag{3}$$

and is indifferent to the location of the FDI if $W_i = 0$. As pre-tax profits are assumed to be the same for the firm regardless of where it locates, $b_i - b_j$ is the difference in the firm's net profits from choosing to invest in country i.

3 Simultaneous bidding under complete information

We start with a sealed-bid auction, identical to that of Ferrett and Wooton (2010), where the governments make their offers simultaneously and irreversibly. This yields a multiplicity of Nash equilibria. Ferrett and Wooton restrict their attention to outcomes where the countries

[8]This preference for local production can be attributed to a number of causes. In Haufler and Wooton (1999) it arises because locally produced goods are cheaper than imports from the other country. Among other justifications for the desire to attract FDI are the increased demand for domestic workers that it generates and the technological spillovers to indigenous industries from the increased the manufacturing activity.

do not make weakly dominated bids. Thus neither country ever makes a bid higher than its valuation of the investment.[9] We shall, at least initially not impose this limitation on the potential equilibria.

Given that pre-tax profits of the firm are the same in both potential host countries, country A wins the auction only if

$$b_A \geq b_B.$$

country A will surely win if it offers the firm a larger subsidy or lower tax than its rival, country B.

Consider country A's best response to its rival's bid b_B. We show that country A should offer:

$$\text{(i)} \quad b_A = -\pi \text{ if } b_B < -\pi;$$

$$\text{(ii)} \quad b_A = b_B + \varepsilon \text{ if } -\pi \leq b_B < S_A;$$

$$\text{(iii)} \quad b_A \in (-\infty, b_B] \text{ if } b_B = S_A; \text{ and}$$

$$\text{(iv)} \quad b_A \in (-\infty, b_B) \text{ if } b_B > S_A,$$

where $\varepsilon > 0$ is an arbitrarily small number. These bids are explained as follows. (i) If country B were to set tax greater than the firm's pre-tax profits, the firm would make a loss if it located in that country and would never invest there. All that country A needs to do in order to attract the firm is to make an offer that would allow it at least to break even, that is $b_A + \pi \geq 0$. Thus, country A's optimal strategy is to set tax such that it fully extracts the firm's profits from the FDI. (ii) Were country B to offer a smaller tax (or grant a subsidy) to the firm such that it would makes an after-tax profit from its FDI, country A would have to improve on its offer in order to win the auction. The winning bid is a tax/subsidy that gives the firm ε more in after-tax profits than it would get from locating in country B. (iii) There are limits to country A's generosity, however, as it will only be prepared to offer a subsidy

[9] This rules out cases where a country would lose if it were to succeed in attracting the firm and makes a high offer only because it is certain that the firm will reject the overly generous subsidy in favour of a better deal being offered by the other country which values the investment more highly. Indeed, it can be shown that country i's offering at its own valuation S_i weakly dominates any offer that is strictly higher than S_i.

up to its valuation of the FDI when it has a chance of winning the auction. If country B were to offer a subsidy equal to country A's valuation such that $b_B = S_A$, country A has two options. It can either try to attract the FDI by matching country B's bid. In such a case, it follows from (3) that $W_A = 0$, meaning that country A receives no benefit from the investment. Otherwise, country A could make a lower bid that would ensure that it lost the auction. Thus, regardless of whether or not country A wins the auction, it receives W_{AB}. (iv) If country B bids above country A's valuation of the investment, any bid that would beat country B's offer would result in $W_A < 0$ and consequently country A will ensure that it loses. Country B's best response function is derived in an identical fashion.

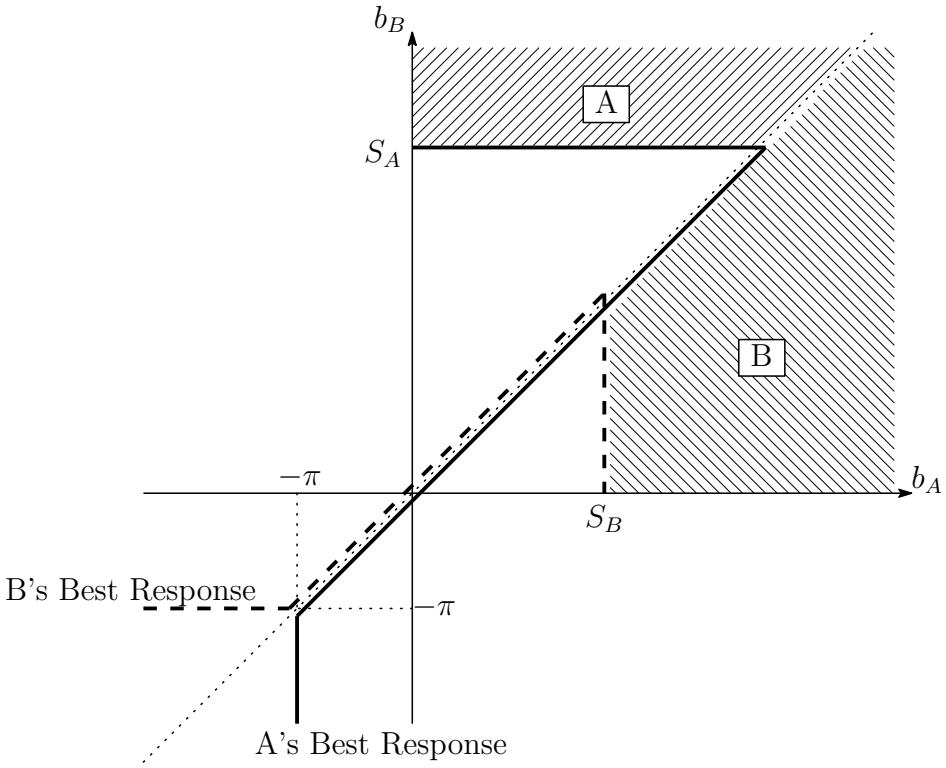

Figure 1: Simultaneous Bidding

Figure 1 depicts the two countries' reaction curves in the case where $S_A > S_B$. There are multiple Nash equilibria, such that country B offers a subsidy in the range $b_B^* \in [S_B, S_A]$ while country A wins the auction by matching its rival's subsidy with $b_A^* = b_B^*$. It is easy to see that, given country A wins the auction, neither country has an incentive to deviate from

their prescribed strategies. Country A's equilibrium bid can be viewed as the limit strategy as ε goes to zero. Country A attracts the FDI at minimum cost, given its rival's bid, so has no incentive to deviate. Country B, on the other hand, wishes to lose the contest given country A's bid, and this is the outcome in equilibrium.

If the two countries had identical valuations of the FDI, $S = S_A = S_B$, then each country would bid its valuation and the equilibrium bids would be identical, $b_A^* = b_B^* = S$. The firm would then be indifferent between locations and might invest in either country. The winning nation would be no better off than the loser, as all of the rent from the investment would be transferred to the firm in the subsidy. This is the familiar "race to the bottom" in taxes.

Ferrett and Wooton's (2010) result, that the international distribution of the firm's ownership is irrelevant to the outcome of the game, can be understood by considering the objective function of country i given by (3). The citizens' ownership of the firm e_i is multiplied by the difference in the two countries' bids; the citizens in country i capture the fraction e_i of their country's bid but lose the opportunity to capture the same fraction of the rival nation's bid. It might seem that this should influence the equilibrium offers and perhaps the location of the FDI. However, the bids made by the countries are such that the firm is only *just* persuaded to locate in one location over the other. Thus, in equilibrium, the bids are equal because the firm considers the two locations as being equally attractive. Consequently the first term in (3) is zero with domestic shareholders being unaffected by the equilibrium location of the FDI. Thus the distribution of ownership of the firm has no effect on the strength of national bids nor on the eventual locational choice of the firm in equilibrium.

Proposition 1 *In the sealed-bid, first-price auction, there exist multiple Nash equilibria unless $S_A = S_B$. If $S_A > S_B$, country A attracts the investment with a winning bid $b_A^* \in [S_B, S_A]$. If $S_A = S_B$, the location of the firm is indeterminate and the entire benefit of the investment is transferred to the firm through the equilibrium bids of $b_A^* = b_B^* = S$. Furthermore, the international distribution of the firm's ownership does not affect the countries' bidding strategies.*

Let $S_A > S_B$. If country B's equilibrium bid is equal to its valuation of the FDI, that

is $b_B^* = S_B$, then country A will win the auction with the minimum subsidy by matching country B's subsidy. If $b_B^* \in (S_B, S_A)$, country B's equilibrium bid is strictly greater than S_B, its valuation of the FDI. Country B can make such a bid because it "knows" that country A will match the bid in order to win the auction.

Although this argument is important in understanding the equilibrium in later sections, one may argue that such Nash equilibria are not appealing. Indeed, any bid b'_B that is strictly greater than S_B is dominated by $b_B = S_B$. We can demonstrate this by considering the best response of country B to any bid b_A. (i) If $b_A < S_B$, then $b_B = S_B$ is strictly preferable to $b_B = b'_B$ because country B would still win the auction with less payment to the firm. (ii) If $S_B \leq b_A < b'_B$, then $b_B = S_B$ is strictly preferable to $b_B = b'_B$ because winning the auction in this case entails a loss for country B as $e_B(b'_B - b_A) - b'_B + S_B \leq S_B - b_A \leq 0$. (iii) If $b_A = b'_B$, then $b_B = S_B$ is preferable to $b_B = b'_B$ should country B win the auction while it would be indifferent between them when country A wins. Finally, (iv) if country A bids $b_A > b'_B$, then country B is indifferent between $b_B = S_B$ and $b_B = b'_B$. Similarly, a bid by country A's that exceeds S_A is dominated by $b_A = S_A$. Thus each country offers at most its valuation of the FDI in its undominated strategies. Consequently, the undominated Nash equilibrium, which is the Nash equilibrium with a pair of undominated strategies, is uniquely determined as $b_A^* = b_B^* = S_B$, with country A winning the auction.[10]

Proposition 2 *There exists a unique undominated Nash equilibrium in which $b_A^* = b_B^* = S_B$ and the firm locates itself in country A. The winning bid is the minimum bid of all the Nash equilibrium bids.*

4 An English auction under complete information

We now change the first stage of the game to that of an English auction, in which each country has the opportunity to respond to the bid of its rival. It might be argued that this better reflects the reality of inter-governmental competition for investment, in that the firm can play potential host countries off against each other and thereby extract the highest offer.

[10]The undominated Nash equilibrium is the outcome considered by Ferrett and Wooton (2010).

We therefore allow each country the chance to bid an amount Δ above the standing bid of its rival. Recall that we are assuming that pre-tax profits are the same in both locations for the firm, consequently the winner will be the country whose standing bid does not attract an improved bid from the other nation.

Let country j's standing bid be b_j. Given country i's net welfare benefit of hosting the firm given by (3), it will raise its bid to $b_i = b_j + \Delta$ if and only if

$$S_i \geq b_j + (1 - e_i)\Delta. \tag{4}$$

That is, country i will improve its bid as long as the additional cost (that part of the extra incentive that does not accrue to shareholders in country i) does not push the cost of the subsidy beyond the country's valuation of the FDI should it become the host nation. Whenever (4) holds for country i, following a bid by its rival it will bid again and the cycle will continue. We derive the limit equilibrium as Δ goes to zero. It follows from (4) that in the limit equilibrium, country i raises its bid as long as $S_i > b_j$.

Consider the case in which $S_A > S_B$ and examine whether or not country B has an incentive to raise its bid beyond its valuation when $b_A \in (S_B, S_A)$. Country B knows that country A will reply to its bid of $b_B = b_A + \Delta$ for a small Δ as long as the counterbid does not exceed country A's valuation, that is $b_A + 2\Delta \leq S_A$. Therefore, country B can raise A's winning bid from b_A to $b_A + 2\Delta$ if it offers $b_A + \Delta$ and make no bid in the succeeding round. In following this strategy, country B gains $2\Delta e_B$ relative to its having stopped bidding in the earlier round.

If citizens of country B have no ownership shares in the firm ($e_B = 0$), there exist multiple subgame perfect equilibria whose outcomes are the same as in the case of the sealed-bid auction. Country A's winning bid must be at least S_B, otherwise country B would continue to bid. Moreover, B is indifferent to any $b_A \in [S_B, S_A]$ so long as it loses, since it gets S_{BA} in any event. Country B also knows that its bid will be countered if country A's bid is in this range. So the eventual loser can raise country A's winning bid to any level in this range. As with simultaneous bidding, the undominated subgame perfect equilibrium outcome is that

country A wins the auction with its winning bid of S_B.

On the other hand, if part of the firm is owned by the citizens of country B (that is, $e_B > 0$), the subgame perfect equilibrium will be unique and characterized by country A winning with a bid of S_A. This is because country B knows that country A will be prepared to raise its bid as long as $b_A < S_A$. Consequently country B will bid beyond its own valuation of the FDI in order to force up the payment to the firm, as a share of this subsidy is paid to its own citizens. This result contrasts sharply with those in the previous literature, such as Haufler and Wooton (1999) as well as our the benchmark case, in which the winning nation need only offer as much as the rival's valuation of the firm. Moreover, it is also different from the result of Ferrett and Wooton (2010) in that the firm's ownership structure affects the equilibrium outcome significantly.

If $S_A = S_B \equiv S$, then either country A or B wins the auction with its winning bid of S.

Proposition 3 *In an English auction under complete information when $S_A > S_B$, the subgame perfect equilibrium depends on the value of e_B. If $e_B = 0$, the equilibrium outcomes are the same as in the case of sealed-bid first-price auction with multiple subgame perfect equilibria, although the undominated subgame-perfect equilibrium is uniquely determined with country A's winning bid of S_B. If $e_B > 0$, there exists a unique subgame perfect equilibrium in which country A wins the auction with its winning bid of S_A. If $S_A = S_B = S$, the location of the firm is indeterminate and the entire benefit of the investment is transferred to the firm through an equilibrium bid of S.*

5 Simultaneous bidding under incomplete information

Let us now examine the effect of incomplete information about countries' valuations of the FDI on the outcome of the simultaneous bidding. We assume that the benefits received both from attracting FDI and from importing are a country's private information. That is, S_{ii} and S_{ij} are known only to country i. However, we assume that the probability distribution of country i's valuation of the investment $S_i(\equiv S_{ii} - S_{ij})$ is common knowledge. Let $F_i[S_i]$ be the cumulative distribution function with a corresponding continuous density function of

$f_i[S_i]$.

Let $\tilde{b}_i(S_i)$ denote the equilibrium bidding of country i as a function of its valuation of the FDI. Country A, for example, wins the auction and obtain $e_A(\pi + b_A) - b_A + S_{AA}$ if $b_A \geq \tilde{b}_B(S_B)$, and loses the auction and obtain $e_A(\pi + \tilde{b}_B(S_B)) + S_{AB}$ otherwise. Thus, country A chooses b_A to maximize

$$\int_{S_B \leq \tilde{b}_B^{-1}(b_A)} [e_A(\pi + b_A) - b_A + S_{AA}] f_B[S_B] dS_B + \int_{S_B > \tilde{b}_B^{-1}(b_A)} [e_A(\pi + \tilde{b}_B(S_B)) + S_{AB}] f_B[S_B] dS_B.^{11}$$

The first-order condition for this maximization problem can be written as

$$\left(\tilde{b}_B^{-1}\right)'(b_A) f_B[\tilde{b}_B^{-1}(b_A)] \left\{ e_A[b_A - \tilde{b}_B(\tilde{b}_B^{-1}(b_A))] - b_A + S_A \right\} = (1 - e_A) F_B[\tilde{b}_B^{-1}(b_A)]. \quad (5)$$

The left-hand side of (5) shows the expected benefit from raising the bid slightly from b_A. The chance of winning increases if $\tilde{b}_B(S_B)$ equals b_A, the probability density of whose event equals $\left(\tilde{b}_B^{-1}\right)'(b_A) f_B[\tilde{b}_B^{-1}(b_A)]$. By winning the auction, country A's shareholders as a whole obtain $e_A b_A$ instead of $e_A \tilde{b}_B(\tilde{b}_B^{-1}(b_A))$. This gain is obviously nil because increasing the bid slightly from b_A would change the winner from B to A only when $b_B(S_B)$ is equal to b_A. Therefore, the net welfare gain from overturning the auction result equals $S_A - b_A$. The right-hand side of (5) shows, on the other hand, the expected loss from raising the bid. With probability $F_B[\tilde{b}_B^{-1}(b_A)]$, country A wins the auction even without raising the bid. Thus, in such cases, country A would lose the fraction $1 - e_A$ of the increment of the bid by raising the bid unnecessarily.

We can solve (5) for b_A to obtain country A's bidding function, which is implicitly defined by

$$\tilde{b}_A(S_A) = S_A - \frac{(1 - e_A) F_B[\tilde{b}_B^{-1}(\tilde{b}_A(S_A))]}{(\tilde{b}_B^{-1})'(\tilde{b}_A(S_A)) f_B[\tilde{b}_B^{-1}(\tilde{b}_A(S_A))]}. \quad (6)$$

We find from (6) that $\tilde{b}_A(S_A) < S_A$ if $e_A < 1$. Country A's bid approaches S_A as e_A increases to one. Similarly, we can readily obtain country B's bidding function as

$$\tilde{b}_B(S_B) = S_B - \frac{(1 - e_B) F_A[\tilde{b}_A^{-1}(\tilde{b}_B(S_B))]}{(\tilde{b}_A^{-1})'(\tilde{b}_B(S_B)) f_A[\tilde{b}_A^{-1}(\tilde{b}_B(S_B))]}.$$

[11] Without loss of generality, we may assume that country A wins the auction when the two countries' bids are equal.

Proposition 4 *In the presence of incomplete information regarding the other country's valuation of the FDI, each country's bid is smaller than its own valuation. The bid increases, however, with the share of the firm owned by its citizens.*

Recall that if the countries' valuations are common knowledge, each country is willing to raise the bid up to its own valuation, but they both choose the bid equal to the smaller of the nations' valuations as their undominated strategies. Under incomplete information, neither country knows which has the lower valuation of the FDI. Therefore, they both make bids that are lower than their own valuations, in order to capture a positive net benefit should they win the auction. Their bids increase with their ownership shares of the firm, since their own citizens re-capture a part of their bids in proportion to their shares of the firm. Hence the effective costs of countries raising their bids are lower when they have larger ownership shares.

6 An English auction under incomplete information

Finally, we consider what might be the most relevant form of tax competition in practice: the English auction under incomplete information about countries' valuations of the FDI. As in the previous section, country i's valuation S_i is private information although its probability distribution, characterized by a cumulative distribution function $F_i[S_i]$, is common knowledge.

Country i's strategy in the English auction for the FDI is characterized by its threshold of dropping out of the auction. Country i will only counterbid if the expected payoff from raising the standing bid by Δ is not less than the guaranteed payoff from dropping out of the auction and letting its rival attract the FDI. This permits us to determine country i's *threshold bid* as $\bar{b}_i(S_i)$, the value of the standing bid at which the expected returns from staying in the auction and from dropping out are equalized. Thus, country i will only stay in the auction, making a counterbid to country j if the latter's last bid is below country i's threshold bid, that is $b_j \leq \bar{b}_i(S_i)$.

country A, for example, counters the standing bid b_B if the expected payoff from making

a bid of $b_A = b_B + \Delta$ is greater than or equal to that from dropping out of the auction immediately. If country A does make a new bid, there are two possible outcomes. First, it would win the auction if country B does not to respond with its own counterbid. This would arise with probability

$$\begin{aligned} P_B(b_B + \Delta) &\equiv \text{Prob}[b_B + \Delta > \bar{b}_B(S_B) | b_B - \Delta \leq \bar{b}_B(S_B)] \\ &= \frac{F_B[\bar{b}_B^{-1}(b_B + \Delta)] - F_B[\bar{b}_B^{-1}(b_B - \Delta)]}{1 - F_B[\bar{b}_B^{-1}(b_B - \Delta)]}, \end{aligned} \tag{7}$$

the probability that country A's bid $b_A = b_B + \Delta$ exceeds B's threshold bid $\bar{b}_B(S_B)$ conditional on the event that S_B is large enough that B has countered A's previous bid of $b_B - \Delta$, that is $b_b - \Delta \leq \bar{b}_B(S_B)$. The second outcome is where country B does respond to country A's bid with a higher offer (after which country A will have to decide once again whether to make a further bid), which would arise with probability $1 - P_B(b_B + \Delta)$. Country A calculates the expected payoff that it would receive from making a new bid and compares this to the guaranteed payoff from dropping out of the auction without further bidding.

Since country A's expected payoff from making a new bid is at least as large as the expected payoff from making a new bid and dropping out of the auction in its next turn if the new bid is countered by B, it will stay in the auction and make a new bid if and only if

$$\begin{aligned} &[e_A(\pi + b_B + \Delta) - (b_B + \Delta) + S_{AA}]P_B(b_B + \Delta) + [e_A(\pi + b_B + 2\Delta) + S_{AB}][1 - P_B(b_B + \Delta)] \\ \geq\ & e_A(\pi + b_B) + S_{AB}. \end{aligned} \tag{8}$$

If $P_B(b_B + \Delta) = 0$, the first term of (8) is zero and country B will definitely continue to bid. In this case, it is certainly worthwhile for country A to make a further bid, even if it eventually loses the auction, as the payment made to citizens owning some shares of the firm is driven up. If, at the other extreme, $P_B(b_B + \Delta) = 1$ and country A's next bid would certainly win the auction, the decision as to whether to make a further bid depends upon country A's valuation of the FDI relative to the cost of attracting it, that is whether S_A exceeds $b_B + (1 - e_A)\Delta$. This argument is made more transparent if we rewrite (8) by subtracting the right-hand side from the left-hand side as

$$[S_A - b_B - (1 - e_A)\Delta]P_B(b_B + \Delta) + 2\Delta[1 - p_B(b_B + \Delta)] \geq 0. \tag{9}$$

Substituting (7) into (9), we obtain a new condition for country A to be prepared to make a further bid

$$\frac{[e_A\Delta-(b_B+\Delta)+S_A]}{1-F_B[\bar{b}_B^{-1}(b_B-\Delta)]}\frac{F_B[\bar{b}_B^{-1}(b_B+\Delta)]-F_B[\bar{b}_B^{-1}(b_B-\Delta)]}{2\Delta}+e_A\frac{1-F_B[\bar{b}_B^{-1}(b_B+\Delta)]}{1-F_B[\bar{b}_B^{-1}(b_B-\Delta)]}\geq 0.$$

Once again, we let $\Delta\to 0$ to obtain

$$(S_A-b_B)\frac{f_B[\bar{b}_B^{-1}(b_B)]\bar{b}_B^{-1\prime}(b_B)}{1-F_B[\bar{b}_B^{-1}(b_B)]}+e_A\geq 0,$$

where $\bar{b}_i^{-1\prime}(b_i)=d\bar{b}_i^{-1}(b_i)/db_i>0$. This can be rewritten as

$$b_B\leq S_A+\frac{\bar{b}_B'(\bar{b}_B^{-1}(b_B))\{1-F_B[\bar{b}_B^{-1}(b_B)]\}}{f_B[\bar{b}_B^{-1}(b_B)]}e_A, \tag{10}$$

where we have used $\bar{b}_B^{-1\prime}(b_B)=1/\bar{b}_B'(\bar{b}_B^{-1}(b_B))$. Thus country A would be prepared to make a further bid if (10) is satisfied.

The threshold bid for country A, $\bar{b}_A(S_A)$, is determined implicitly as b_B that satisfies (10) with equality. Thus, country A's threshold bid can be written as

$$\bar{b}_A(S_A)=S_A+\frac{\bar{b}_B'(\bar{b}_B^{-1}(\bar{b}_A(S_A)))\{1-F_B[\bar{b}_B^{-1}(\bar{b}_A(S_A))]\}}{f_B[\bar{b}_B^{-1}(\bar{b}_A(S_A))]}e_A. \tag{11}$$

Similarly, we obtain country B's threshold bid as

$$\bar{b}_B(S_B)=S_B+\frac{\bar{b}_A'(\bar{b}_A^{-1}(\bar{b}_B(S_B)))\{1-F_A[\bar{b}_A^{-1}(\bar{b}_B(S_B))]\}}{f_A[\bar{b}_A^{-1}(\bar{b}_B(S_B))]}e_B. \tag{12}$$

Observe in (11) and (12) that if $e_i=0$, then $\bar{b}_i(S_i)=S_i$. Country i has no incentive to bid above its valuation of S_i and risk "winning" the auction in order to push up the rival country's bid, as none of this will benefit citizens in country i. If on the other hand $e_i>0$, country i is willing to take a risk to try to raise the winning bid hoping that its rival eventually wins the auction. The threshold bid balances the cost of potentially winning the auction with a bid above the country's valuation and the benefits of an increase in the payout to shareholders should the country lose the auction.

Proposition 5 *In the English auction under incomplete information, if $e_i=0$ then each country i continues to bid until the standing bid reaches its own valuation of the firm S_i, otherwise when $e_i>0$ it bids beyond its valuation. The higher is e_i, the higher is the threshold bid. As a consequence, a country that has some ownership of the firm may lose by winning the auction.*

6.1 An example

To gain more insights of the result, let us specify the probability distribution as the exponential distribution with the support $[a, \infty)$, i.e.,

$$\begin{aligned} F_i[S_i] &= 1 - e^{-\lambda_i(S_i - a_i)}, \\ f_i[S_i] &= \lambda_i e^{-\lambda_i(S_i - a_i)}. \end{aligned}$$

This probability distribution has a mean of $a_i + 1/\lambda_i$ and a variance of $1/\lambda_i^2$. Moreover, we have for $i = A, B$

$$\frac{1 - F_i[\bar{b}_i^{-1}(b_j)]}{f_i[\bar{b}_i^{-1}(b_j)]} = \frac{1}{\lambda_i},$$

for any b_i. Thus, threshold bids expressed in (11) and (12) can be rewritten as

$$\begin{aligned} \bar{b}_A(S_A) &= S_A + \frac{e_A}{\lambda_B}, \\ \bar{b}_B(S_B) &= S_B + \frac{e_B}{\lambda_A}. \end{aligned}$$

The larger the share of the firm held by a country, the greater its willingness to continue in the auction, in order to push up the expected redistribution of after-tax profits to its own citizens. Moreover, the higher the mean (and hence the variance) of the rival country's valuation, the greater its willingness to continue the auction, since the risk of winning the auction is smaller when it raises the bid at any stage of the auction.

To further examine the properties of the equilibrium, let us look at several specific cases.

1. $S_A > S_B$ and $e_A = e_B = 0$.

   country A wins with the winning bid of S_B. The outcome is the same as those in both simultaneous bidding under complete information and the undominated subgame perfect equilibrium outcome when $e_B = 0$ in the English auction under complete information. It is worthwhile to note that, in the English auction, making the information about countries' valuations private (as opposed to public) eliminates all of the subgame-perfect equilibria with winning bids by country A higher than its evaluation S_A. This is because, when the information is incomplete, country B is no longer confident that country A would match B's bid beyond S_B.

2. $S_A > S_B$ and $e_A/\lambda_B = e_B/\lambda_A > 0$.

   country A wins with the winning bid of $S_B + (e_B/\lambda_A)$. The winning bid may exceed country A's valuation S_A if e_B is large or λ_A is small; country B's threshold bid is high if country B has a large incentive to raise the rival country's winning bid (i.e., e_B is large) or if the risk of country B's winning with a bid beyond S_B is small (i.e., λ_A is small). Note also that this outcome is more likely to occur if e_A is large or λ_B is small so that country A's threshold bid is more likely to exceed that of country B.[12]

3. $S_A = S_B$ and $e_A/\lambda_B = e_B/\lambda_A > 0$.

   Either country A or country B wins the auction with the winning bid of $S_A + (e_A/\lambda) = S_B + (e_B/\lambda)$, which certainly exceeds the winner's valuation of the FDI. The two countries "race beyond the bottom" if they are symmetric.

4. $S_A > S_B$ and $S_A + (e_A/\lambda_B) < S_B + (e_B/\lambda_A)$.

   Country B wins the auction even though country A's valuation of the FDI is higher than that of country B. The resulting location of the firm is inefficient, and country B certainly loses by winning the auction.

We summarize some of the above findings in the following proposition.

Proposition 6 *In the English auction under incomplete information, a country may lose by winning the auction. This "race beyond the bottom" is more likely to occur if e_A and e_B are large and λ_A and λ_B are small so that the countries' threshold bids are large. The country with a lower valuation of the FDI than the other may win the auction if its citizens hold a large share of the firm or if the mean of the other country's valuation of the FDI is large.*

7 A comparison

Having analyzed the auction for the investment in the four different auction environments, we now compare the outcomes of the auctions and investigate how the auction protocol and

[12] In this example, $e_A/\lambda_B = e_B/\lambda_A$.

asymmetry of information affect the auction results. To simplify the exposition, we assume here that $e_i > 0$ for $i = A, B$.

Let us first examine the role of auction protocol, assuming that the countries' valuations are common knowledge. In such cases, each country i is willing to raise its bid up to its own valuation S_i in order to win the auction (see (3) and note that only if $b_j = b_i$ will country i become a winner by slightly raising its bid). Under complete information on the countries' valuations, both nations know which country will win and which will lose. The winner wants to lower the bid as much as possible, while the loser wants to induce the winner to raise the winning bid, so that its share-holding citizens can capture more dividends. In simultaneous bidding, changing the bid would not affect the other country's bid, so the loser cannot induce the winner to raise the winning bid by raising its own bid. Thus, the equilibrium bids of the two countries coincide with the smaller of the countries' valuations. In the English auction, on the other hand, the loser can raise the winner's bid by bidding up to the winner's valuation. Consequently, the winning bid equals the higher of the countries' valuations.

Now, we turn to the role of information asymmetry. Under incomplete information on the countries' valuations, neither country knows which will be the winner. Consequently, each country acts partly as a potential winner and partly as a potential loser. Consequently, in simultaneous bidding each country makes a bid smaller than its own valuation. Suppose that the realized valuations of either country are the same for both the case of complete information and that of incomplete information, such that $S_B < S_A$. In equilibrium, country A's winning bid equals S_B under complete information, while it is smaller than S_A (which may or may not be smaller than S_B) under incomplete information. The winning bid is likely to become smaller with the asymmetry of information if S_A and S_B are close to each other. In the English auction, on the other hand, each country makes a bid that is higher than its own valuation, as opposed to making a bid lower than its own valuation in the case of simultaneous bidding. Country A's winning bid equals S_A under complete information, while it is strictly greater than S_A under incomplete information. The asymmetry of information

unambiguously raises the equilibrium winning bid.

Thus the equilibrium bid tends to be higher when a more-realistic bidding environment is adopted. Bidding for a firm features not just a "race to the bottom" but more of a "race beyond the bottom."

8 Conclusion

This paper has investigated countries' bidding strategies for a firm and the resulting equilibrium bids across a wider range of bidding environments than are traditionally examined. We have found that when citizens of bidding countries own shares of the firm, the equilibrium winning bid is greater in an English auction than in simultaneous bidding. Asymmetry of information on countries' valuations of the firm's investment further increases the winning bid in the English auction, while there is ambiguity as to whether it increases or decreases the winning bid under simultaneous bidding. In, what we argue is, a more realistic bidding environment for FDI, countries bid for a firm more aggressively causing the "race beyond the bottom." in which an inefficient allocation of the FDI may also arise.

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