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Industrial Groupings and Strategic FDI.

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Abstract

We show that industrial ownership structures, such as *keiretsu* groupings in Japan, may significantly impact firms' incentives to engage in FDI. While the previous literature has mainly focused on the cost of capital advantages enjoyed by *keiretsu* firms, this paper examines two relatively unexplored channels by which ownership structure matters for FDI incentives. The first channel involves the direct incentives generated via standard product and factor market interactions whereby *keiretsu* firms with cross-ownership consider more directly the congestion effects of further FDI into a market. The second channel involves the indirect incentives generated by sharing of information across *keiretsu* firms which reduces entry costs of subsequent FDI. We find that *keiretsu* firms are more agressive than *non-keiretsu* firms in their FDI strategies, that is, for any given parameter values they undertake FDI with a higher probability than independent firms. Furthermore, *keiretsu* firms adopt a more agressive investment strategy against independent rivals than amongst themselves.

Keywords: Foreign direct investment; keiretsu.

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1 Introduction.

It has frequently been suggested that firms in the large industrial groupings of Japan and Korea, known respectively as *keiretsu* and *chaebol*, may behave differently from their US or European counterparts or independent domestic rivals. Members of these industrial groupings hold ownership shares in each other, obtain repeated financing from associated member banks, and participate on joint committees.[1] For each of these reasons it has been argued that the structure of *keiretsu* and *chaebol* lead their member firms to behave (semi)cooperatively. Consequently, they may be expected to internalize externalities and find ways to mitigate the problems implied by information asymmetries.[2] It has been further noted that cross-shareholding structures can also weaken a firm's bargaining position and dilute its market incentives, Flath [6] Flath [7].

The purpose of this paper is to explore the relationships between industrial ownership structure and the incentives for firms to carry out foreign direct investment (FDI). It has been alleged that (semi)cooperative industrial ownership structures, such as the Japanese *keiretsu* system, yield their members advantages in exploiting opportunities for FDI. Typically these advantages are explained as arising from access to cheap funds for investment. While these stories seem quite plausible, the empirical support for them has been somewhat mixed (see Belderbos and Sleuwaegen [2], Hoshi, Kashyap, and Scharfstein [10], Fukao, Izawa, Kunimori and Nakakita [9], and McKenzie [13]). In this paper we take a different approach. Rather than concentrate on the implications of ownership structure for the financing of FDI, we instead focus, first, on the implications it has for the strategic incentives to invest that arise through the interactions between firms on input and output markets, and, second, on the incentives it provides for information generation and dissemination.

We first develop an illustrative theoretical model similar to that proposed in the literature on the adoption of new technology by Fudenberg and Tirole [8]. FDI decisions are modelled as

[1] Bank representatives also sit on the boards of associated firms.
[2] See for example Suzuki [17], Dewenter and Warther[3], Kimura and Pugel [11].

entry probabilities in a mixed strategy equilibrium to a game in stages. We model the factor and product market interactions by allowing the firms' payoffs to change as successive entry takes place. The information aspect of the process is captured by assuming that entry costs are a declining function of the total number of prior investments. To further capture the salient features of the FDI process we assume some information is public, and is generated as an externality to be enjoyed by all potential entrants, whereas some of the information is private, and is only transmitted between firms engaged in cooperative relationships.

Modelling FDI decisions as entry probabilities in a mixed strategy equilibrium has previously been proposed by Lin and Saggi [12] and Ellis and Fausten [4]. Our analysis, though still not fully general, considerably extends these earlier contributions. Linn and Saggi examined a single stage game between two competitive firms so as to obtain the comparative statics properties of the initial entry probability decision, and the optimal delay between initial and subsequent entry. Ellis and Fausten followed the same path as Linn and Saggi but introduced overlapping share ownership into the model to analyze the implications for FDI of different ownership structures. Our work makes two key further extensions; we introduce a third firm into the analysis and allow for asymmetric information between firms. Introducing a third firm might seem minor, yet it is significant in three ways; (1) It allows us to consider strategic interactions between a pair of (semi)cooperative firms and a competitive rival; (2) It allows the FDI entry game to be split into a sequence of stages, each of which is characterized by equilibrium entry probabilities, allowing examination of the relationships between entry probabilities over time; and, (3) It allows private information to play a significant role, as an early entrant must consider the subsequent asymmetries in information that may be generated by its entry.

2 The Model.

When firms contemplate locating production facilities outside of their home countries they face a difficult trade-off. If they invest early they may gain advantages on both product and input markets. However, in moving early they also face a host of potential problems. For example, it takes time to learn how to operate efficiently in a foreign labor market and under a foreign legal system. Thus the initial fixed costs of investment may be high. If, on the other hand, they delay entry, they will forgo some of the product and factor market advantages enjoyed by early entrants, but may gain valuable information from observing their predecessors. This information will reduce the fixed costs of initial entry. The theoretical model we now develop captures this basic tension.

2.1 Basic Structure.

We assume that there are three firms that may produce output either in their domestic economy(ies) or abroad via FDI. The three firms may be either fully independent, as in the case of most US firms or, alternatively, they may be partially cooperative, as for example when linked via overlapping shareholdings, such as in the cases of Japanese *keiretsu* and Korean *chaebol* members.

We assume that initially all three firms are engaged in domestic production, and that at each subsequent point in time each must choose either to continue in this production mode, $m = D$, or make an irreversible switch to foreign production, $m = F$. At any time t the flow profit enjoyed by firm n from choosing a production mode, given the modes of production chosen by the other two firms, is written

$$\Pi^n(t) = \Pi^n \left[m^n(t) \mid m^i(t), m^j(t) \right]$$

$$n = 1, 2, 3, \; i = 1, 2, 3, \; j = 1, 2, 3, \; n \neq i \neq j.$$

Often we shall adopt shorthand notation of the form $\Pi^1\left[D^1(t) \mid D^2(t), F^3(t)\right] \equiv \Pi^1_{DDF}$. In this notation, the firm to whom the profits accrue is always listed first, we then adopt the convention that other firms are listed in ascending sequence, except that 1 will follow 3, that is 1,2,3,1,2 etc.

To capture the idea that there are advantages to early investment we assume that profits will vary across the different combinations of domestic production and FDI. There are two main effects involved in these profit rankings. They may reflect either Cournot or Bertrand competition in the product market (see Linn and Saggi [12]), where early entrants face lower marginal costs and hence a market advantage, or, alternatively, they may purely reflect labor costs. In the cost story FDI allows the firms to exploit cheap labor in the host country, but repeated entry raises labor demand and hence wages in the appropriate foreign labor pool, but lowers demand and wages domestically[3]. The product market story generates the profit ordering

$$\Pi^n_{FDD} > \Pi^n_{FFD} = \Pi^n_{FDF} > \Pi^n_{FFF} > \Pi^n_{DDD} > \Pi^n_{DFD} = \Pi^n_{DDF} \geq \Pi^n_{DFF} \ \forall n.$$

However, the factor market story generates the ordering[4]

$$\Pi^n_{FDD} > \Pi^n_{FFD} = \Pi^n_{FDF} > \Pi^n_{FFF} > \Pi^n_{DFF} > \Pi^n_{DFD} = \Pi^n_{DDF} > \Pi^n_{DDD} \ \forall n.$$

For both profit orderings, in the absence of any relocation costs each firm would *independently* prefer to undertake FDI. This, as we shall see, turns out to be the crucial feature of the profit orderings. In what follows the analytical results obtained are identical for both orderings, while the numerical simulation results display identical qualitative properties and only relatively small quantitative differences. In reality a mix of both stories is, of course, possible. The results reported

[3] For example Feenstra and Hanson [5] find that for regions of Mexico in which FDI is concentrated, more than 50% of the increase in the total wages of skilled workers can be attributed to the effects of foreign capital inflows.

[4] It might be argued that the ordering $\Pi^n_{DDD} > \Pi^n_{DFD}$ should be reversed if there are disadvantages to being the only producer in a specific location, as for example if there are positive spillovers between firms. This has no qualitative implications for our analysis.

in the rest of the paper pertain to the first ordering[5].

To characterize the different potential forms of industrial ownership structure we introduce the parameter β_n^i which represents the claim of firm i on the profits of firm n.[6] So if we denote the total flow profits of firm n as P^n, we may write the possibilities as

$$P^n_{m^n,m^i,m^j} = (1 - \sum_{i \neq n} \beta_n^i)\Pi^n_{m^n,m^i,m^j} + \sum_{i \neq n} \beta_i^n \Pi^i_{m^i,m^j,m^n}$$

$$n = 1,2,3,\ i = 1,2,3,\ j = 1,2,3,\ n \neq i \neq j$$

What distinguishes our model from its antecedents is the ability to analyze strategic FDI when there are both cooperative and non-cooperative firms in the population. We therefore concentrate on this case and assume that firms 1 and 2 are members of a symmetric *keiretsu*, so $\beta_2^1 = \beta_1^2 > 0$, while firm 3 is purely competitive, so $\beta_3^1 = \beta_1^3 = \beta_2^3 = \beta_3^2 = 0$. We may now utilize this structure to examine the firms' FDI decisions in an economy where some firms are linked through industrial groupings and other are not.

2.2 The Firms' Problem.

At some initial date $t = 0$ each firm is engaged exclusively in domestic production.[7] The problem each must solve is if and when to switch to FDI given that switching production from one country to another is clearly costly[8]. We assume that the cost a firm incurs in switching from domestic to foreign production is a decreasing function of the number of firms that have already switched[9].

[5] Numerical simulation programs for both orderings are available from the authors on request.

[6] In the Japanese *keiretsu* system there are other mechanisms by which cooperation may be induced between members. The role of associated commercial banks in providing repeated funding to members, and the placement of bank officials in senior positions in the members hierarchies seem particulaly important. β may therefore be interpreted more widely as a measure of cooperation rather than simply cross shareholdings. See also Aoki [1], Orru, Hamilton and Suzuki [15], and Ouchi [16].

[7] We might think of this as the time at which FDI became a potentially lower cost mode of production. Either because of the relaxation of legal restriction by the host country, an improvement in the host countries labour force, or an increase (real or threatened) in tarrifs for that countries home market etc.

[8] Here we are making the implicit assumption that cross shareholding between firms does not eliminate the direct incentive for firms to undertake FDI . In the simulations that follow we verify this assumption.

[9] We assume that the information allows for the reduction in fixed entry costs. This allows us to model the equilibria in each (sub)game as stationary.

The idea here is that there is cost reducing information that may be obtained by learning from the entry experiences of preceding firms. However, we assume that entry by a *keiretsu* group firm lowers the future entry cost of a fellow group member by more than it lowers the entry cost of a non-member firm. Several interpretations can be given to this assumption. The first, and our preferred, interpretation, is that some of the information is publicly available, but some is private and will be transferred only between firms in the same industrial grouping. In the appendix we show that sharing private information is an individually rational strategy for *keiretsu* member firms. A second interpretation of our asymmetric cost reduction assumption is that all information is public, but information generated by a *keiretsu* firm is of greater cost reducing value to other group firms than to independent firms. Here we are suggesting that similarities in financial structure, similar labor and management practices, and similar cultural backgrounds make the experiences of *keiretsu* firms more valuable to each other than to outsiders[10]. Finally we might argue that the structure of *keiretsu* provides channels for the credible transmission of information between group members firms that are not available between non-member firms. The group member bank may be important in this regard.

We define the entry date of the first firm as $t = t^*$, the second as $t = t^{**}$, and the third as

[10] For this interpretation it makes sense to think of this as a game between keiretsu firms and western competitors.

$t = t^{***}$, naturally $t^* \leq t^{**} \leq t^{***}$. We thus express the entry costs as[11]

$$C(t) = \begin{cases} C^* \text{ which must be common across firms} & \forall t \leq t^* \\ \left.\begin{array}{l} C^{**} \text{ if no private information is revealed at } t^* \\ \underline{C}^{**} \text{ if the entrant at } t^* \text{ reveals private information} \end{array}\right\} & \forall t^* < t \leq t^{**} \\ \left.\begin{array}{l} C^{***} \text{ if no private information is revealed at } t^{**} \\ \underline{C}^{***} \text{ if the entrant at } t^{**} \text{ reveals private information} \end{array}\right\} & \forall t^{**} < t \leq t^{***} \end{cases}$$

$$\text{with } \underline{C}^{***} < \left\{ C^{***} \gtreqless \underline{C}^{**} \right\} < C^{**} < C^*$$

The firms maximize expected profits net of switching costs, which involves each selecting probabilities of FDI at each point in time given those selected by the other firms. We write the probability of firm n switching to FDI as ρ_n. Since this is a game in stages, we also require notation for which firm(s) have already carried out FDI and which have not, consequently $G_{n,i,j}$, will indicate the game where no entry has yet occurred, $G_{n,i}$ the (sub) game where firms n and i have not yet entered, and G_n will be the (sub)game where only firm n has not entered. With this notation probabilities will be written in the form $\rho_n(G_{n,i})$ and so on[12]

The value that a firm obtains from a particular action (F or D) in the game and each sub-game, given the actions of the other firms, will be defined in the form

$$V^1(DDD \mid G_{1,2,3}),$$

which is the value to firm 1 of the action D if both other firms also choose D in the game $G_{1,2,3}$. In a similar vein $V^3(FFD \mid G_{2,3})$ would represent the value to firm 3 of the action F in the subgame

[11] Clearly similar firms may learn more from each other than dissimilar firms will. However, there are common problems such as learning to deal with a foreign legal system and foreign labour markets and practices that are common to all. We thus abstract from differential learning in this paper.

[12] Since each (sub)game is stationary we do not need any further notation to denote time.

$G_{2,3}$, and so on. [13]

2.3 The Extensive Form of the Game.

We are now ready to describe how the process of FDI evolves by presenting the game in extensive form. Figure 1 illustrates the initial situation faced by the three firms.

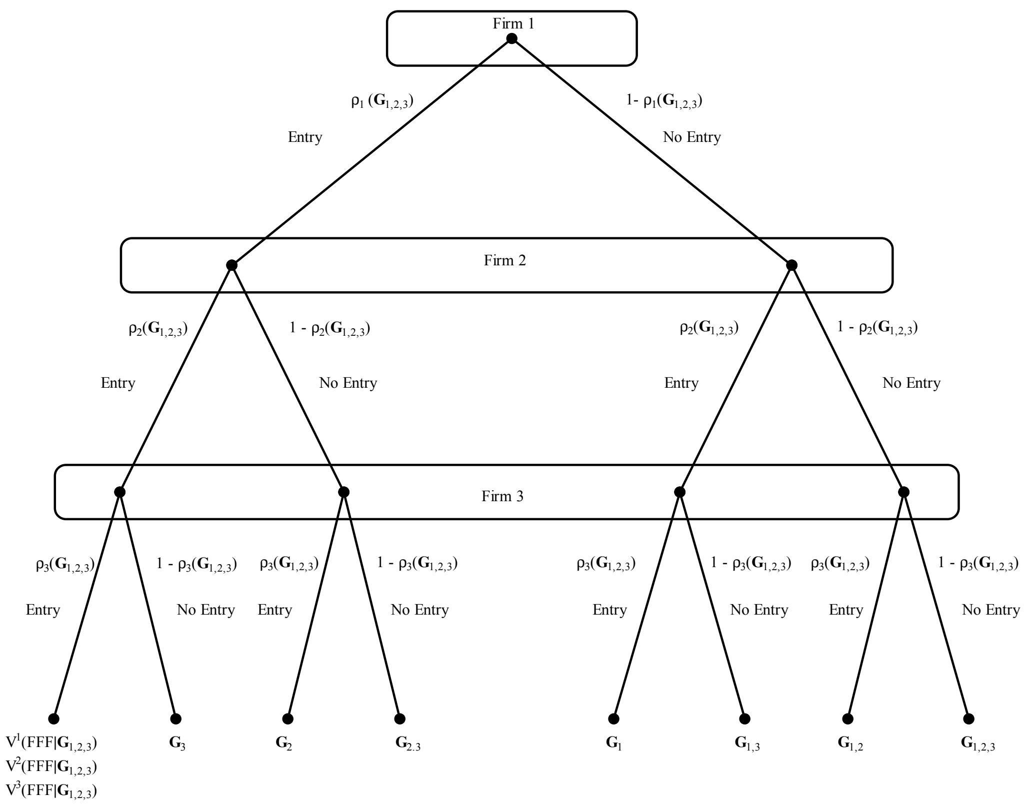

Figure 1: The three firm entry game $G_{1,2,3}$ in extensive form.

Each firm must choose an entry probability, $\rho_n(G_{1,2,3})$, as a best reply to those chosen by the other two firms. Once a firm (or firms) has entered we move to the appropriate subgame. For

[13] Hereafter we shall maintain the assumptions

$$V^n(FFF \mid G_n) < V^n(DFF \mid G_n) \; \forall n$$

which are required to ensure that the whole structure does not unravel backwards with all firms entering instantaneously at the first opportunity.

example, if firm 1 enters in the game $G_{1,2,3}$ then firms 2 and 3 play the subgame $G_{2,3}$ illustrated in figure 2

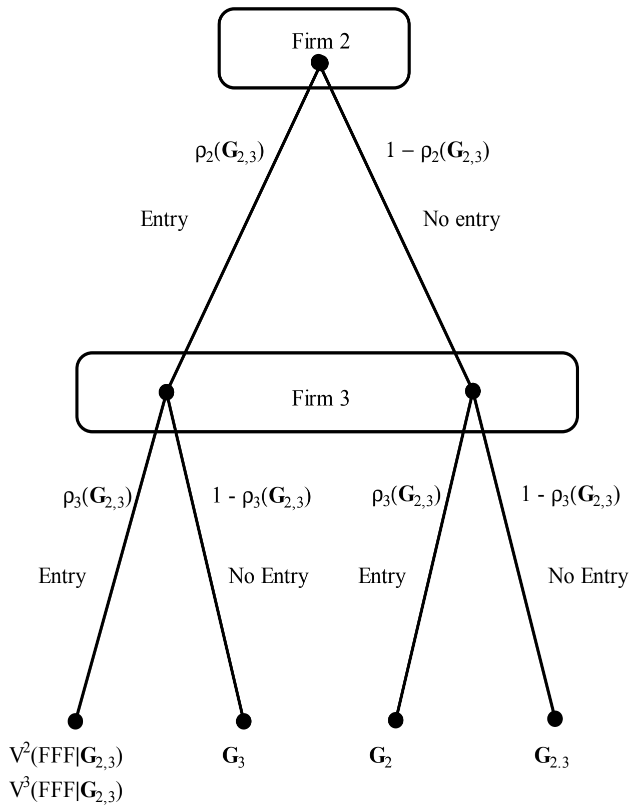

Figure 2: The two firm entry game $G_{2,3}$ in extensive form.

Here the remaining two firms must choose the entry probabilities $\rho_2(G_{2,3})$, and $\rho_3(G_{2,3})$ as best replies .

2.4 Equilibrium.

To obtain the equilibrium of the model we solve recursively for equilibria in each of the potential subgames, starting with $\{G_1, G_2, G_3\}$ then using these values to solve $\{G_{1,2}, G_{1,3}, G_{2,3}\}$, and finally using the values from both $\{G_1, G_2, G_3\}$ and $\{G_{1,2}, G_{1,3}, G_{2,3}\}$ to solve for $G_{1,2,3}$. We thus obtain the subgame perfect equilibrium as a sequence of mixed strategy equilibria in the subgames. Given that firms 1 and 2 are, by assumption, members of a symmetric *keiretsu*, and we have assumed symmetry between these two firms in all other respects, it seems natural to consider symmetric equilibria where $\rho_1(G_{1,2,3}) = \rho_2(G_{1,2,3}) \equiv \rho_{12}(G_{1,2,3})$.

2.4.1 The Third Wave: Entry in the Subgames G_1, G_2, and G_3.

Once two firms have entered the only problem faced by the third is whether to undertake FDI or to continue producing domestically. We shall make the assumption

$$V^n(DFF \mid G_n) > V^n(FFF \mid G_n) \; n = 1, 2, 3.$$

That is, the third firm will always opt for domestic production over FDI. We choose to adopt this condition for both technical and conceptual reasons. Technically the condition is sufficient to ensure that the model does not unravel backwards. Conceptually, if all firms wish to undertake FDI regardless of the presence of other firms, then there can be no interesting strategic interactions in these subgames. One interpretation of this assumption is that previous FDI by two of the three firms is sufficient to bid up factor costs in the inbound jurisdiction to the point where further investment is no longer profitable.

2.4.2 The Second Wave: Entry in the Subgames $G_{1,2}$, $G_{2,3}$, and $G_{1,3}$.

We term the subgames $G_{1,2}$[14], $G_{2,3}$, and $G_{1,3}$ as the second wave of entry. Here one firm has entered and the remaining two firms enjoy information generated by the first entrant. In the games $G_{2,3}$, and $G_{1,3}$ prior entry was by a *keiretsu* member. The remaining *keiretsu* firm enjoys the entry cost reduction $C^* - \underline{C}^{**}$ which reflects both the information generated that is publicly and privately available, whereas the cost reduction for the *non-keiretsu* firm is only $C^* - C^{**}$ reflecting only the publicly available information. In the game $G_{1,2}$ the *non-keiretsu* firm has entered and

[14] With $\beta_2^1 = \beta_1^2 = 0$ this subgame corresponds to the Linn and Saggi op. cit. model. With $1/2 \geq \beta_2^1 = \beta_1^2 \geq 0$ it is the Ellis Fausten op. cit. model.

only reveals the public information, giving the cost reduction $C^* - C^{**}$. The equilibria in these subgames are derived from a value for the subgame and an indifference condition for each of the two firms.[15] For example, in the subgame $G_{2,3}$ (and by symmetry $G_{1,3}$) these involve four expressions[16]. The two indifference conditions

$$\rho_2(G_{2,3})V^3(FFF \mid G_{2,3}) + (1-\rho_2(G_{2,3}))V^3(FFD \mid G_{2,3})$$
$$= \rho_2(G_{2,3})V^3(DFF \mid G_{2,3}) + (1-\rho_2(G_{2,3}))V^3(DFD \mid G_{2,3})$$

and

$$\rho_3(G_{2,3})V^2(FFF \mid G_{2,3}) + (1-\rho_3(G_{2,3}))V^2(FDF \mid G_{2,3})$$
$$= \rho_3(G_{2,3})V^2(DFF \mid G_{2,3}) + (1-\rho_3(G_{2,3}))V^2(DDF \mid G_{2,3}),$$

and the two value functions

$$V^2(DDF \mid G_{2,3}) = \rho_2(G_{2,3})\left[\rho_3(G_{2,3})V^2(FFF \mid G_{2,3})) + (1-\rho_3(G_{2,3}))V^2(FDF \mid G_{2,3})\right]$$
$$+(1-\rho_2(G_{2,3}))\left[\rho_3(G_{2,3})V^2(DFF \mid G_{2,3}) + (1-\rho_3(G_{2,3}))V^2(DDF \mid G_{2,3})\right]$$

and

$$V^3(DFD \mid G_{2,3}) = \rho_3(G_{2,3})\left[\rho_2(G_{2,3})V^3(FFF \mid G_{2,3})) + (1-\rho_2(G_{2,3}))V^3(FFD \mid G_{2,3})\right]$$
$$+(1-\rho_3(G_{2,3}))\left[\rho_2(G_{2,3})V^3(DFF \mid G_{2,3}) + (1-\rho_2(G_{2,3}))V^3(DFD \mid G_{2,3})\right].$$

[15] Details in appendix 2.

[16] In each of these subgames, for there to be a mixed strategy equilibria we require that for each firm neither F nor D is a dominant strategy. Consistent with our prior assumptions we assume that each firm prefers to enter if the other does not, but prefer not to enter if the other does. Again using the subgame $G_{2,3}$ to fix notation this translates into conditions of the form

$$V^2(FDF \mid G_{2,3}) > V^2(DDF \mid G_{2,3}) \geq V^2(DFF \mid G_{2,3}) > V^2(FFF \mid G_{2,3})$$

Substituting in and solving, then repeating the process for the other subgames, provides the equilibrium solutions presented in table 1.

	Subgame.		
	Non-keiretsu entered	*Keiretsu* entered	
Firm	$G_{1,2}$	$G_{1,3}$	$G_{2,3}$
1	$\frac{(1-2\beta)\left(\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FDF}}{r}+C^{**}\right)}{\frac{\Pi^1_{FFF}}{r}-(1-\beta)\frac{\Pi^1_{FDF}}{r}-\beta\frac{\Pi^1_{DFF}}{r}-\beta C^{**}}$	$\frac{\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FDF}}{r}+C^{**}}{\frac{\Pi^1_{FFF}}{r}-\frac{\Pi^1_{FDF}}{r}}$	N/A
2	$\frac{(1-2\beta)\left(\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FDF}}{r}+C^{**}\right)}{\frac{\Pi^1_{FFF}}{r}-(1-\beta)\frac{\Pi^1_{FDF}}{r}-\beta\frac{\Pi^1_{DFF}}{r}-\beta C^{**}}$	N/A	$\frac{\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FDF}}{r}+C^{**}}{\frac{\Pi^1_{FFF}}{r}-\frac{\Pi^1_{FDF}}{r}}$
3	N/A	$\frac{(1-\beta)\left(\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FFD}}{r}+\underline{C}^{**}\right)}{\frac{\Pi^1_{FFF}}{r}-\frac{\Pi^1_{FFD}}{r}}$	$\frac{(1-\beta)\left(\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FFD}}{r}+\underline{C}^{**}\right)}{\frac{\Pi^1_{FFF}}{r}-\frac{\Pi^1_{FFD}}{r}}$

Table 1: Equilibrium entry probabilities for the second wave subgames.

Notice that in the subgames involving a *keiretsu* and *non-keiretsu* firm, $G_{1,3}$ and $G_{2,3}$, the entry probability of the former always exceeds that of the latter, that is

$$\frac{\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FDF}}{r}+C^{**}}{\frac{\Pi^1_{FFF}}{r}-\frac{\Pi^1_{FDF}}{r}} > \frac{(1-\beta)\left(\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FFD}}{r}+\underline{C}^{**}\right)}{\frac{\Pi^1_{FFF}}{r}-\frac{\Pi^1_{FFD}}{r}}.$$

This follows both because the *keiretsu* firm faces lower entry costs, $\underline{C}^{**} < C^{**}$, and because it relinquishes part of its profits to the other *keiretsu* firm. This latter effect follows from the indifference condition that characterizes mixed strategy equilibria. The incentives to enter by a second *keiretsu* firm are diluted both because entry harms the first *keiretsu* firm and because it "loses" some of its profit gain to the first *keiretsu* firm. Thus, for the *keiretsu* firm to be indifferent between entry and delay it must be the case that the entry probability of the *non-keiretsu* firm is relatively lower.

Keiretsu firms also have higher entry probabilities in the subgames where they face independent rivals, $G_{1,3}$ and $G_{2,3}$, than in the subgame where they face each other, $G_{1,2}$, i.e.

$$\frac{\frac{\Pi^1_{DFF}}{r} - \frac{\Pi^1_{FDF}}{r} + C^{**}}{\frac{\Pi^1_{FFF}}{r} - \frac{\Pi^1_{FDF}}{r}} > \frac{(1-2\beta)\left(\frac{\Pi^1_{DFF}}{r} - \frac{\Pi^1_{FDF}}{r} + C^{**}\right)}{\frac{\Pi^1_{FFF}}{r} - (1-\beta)\frac{\Pi^1_{FDF}}{r} - \beta\frac{\Pi^1_{DFF}}{r} - \beta C^{**}}.$$

This can be understood by considering the indifference conditions that characterize mixed strategy equilibria. In the subgames $G_{1,3}$ and $G_{2,3}$ the entry probability of one *keiretsu* firm is required to make the *non-keiretsu* firm indifferent between FDI and domestic production. In the game $G_{1,2}$, this entry probability must make the other *keiretsu* firm indifferent between domestic production and FDI. Everything else equal a *non-keiretsu* firm has greater incentive to enter than a *keiretsu* firm. It retains all of the gains from the action, and does not share in the damage it inflicts on other firms. Thus to make a *non-keiretsu* firm indifferent between domestic production and FDI requires its opponent, that is the *keiretsu* firm, adopt a higher probability of entry than it would otherwise. Hence *keiretsu* firms enter with a greater probability in the subgames where they face *non-keiretsu* firms.

It is now straightforward to derive the comparative statics properties of these subgames, as shown in table 2.

	Entry Probabilities					
	Subgames					
	Non-keiretsu entered		*Keiretsu* firm entered			
	$G_{1,2}$		$G_{1,3}$		$G_{2,3}$	
	$d\rho_1(G_{1,2})$	$d\rho_2(G_{1,2})$	$d\rho_1(G_{1,3})$	$d\rho_3(G_{1,3})$	$d\rho_2(G_{2,3})$	$d\rho_3(G_{2,3})$
$d\beta$	-	-	0	-	0	-
dC^{**}	-[a]	-[a]	-	0	-	0
$d\underline{C}^{**}$	0	0	0	-	0	-
a : For $\frac{\Pi^1_{FDF}}{r} - \frac{\Pi^1_{DFF}}{r} \geq C^{**}$						

Table 2: Comparative statics for the second wave entry probabilities.

We see that in the interesting subgames, $G_{1,3}$ and $G_{2,3}$, those where a mix of *keiretsu* and *non-keiretsu* firms remain, an increase in the *keiretsu* cooperation parameter $d\beta > 0$ lowers the probability of entry by *non-keiretsu* firms, but does not affect the *keiretsu* firms, thus making the relative probability of entry by *keiretsu* members higher. This follows immediately from the nature of the mixed strategy equilibrium, which requires that the probabilities $\rho_3(G_{1,3})$ and $\rho_3(G_{2,3})$ satisfy the indifference conditions for the *keiretsu* firms. As the parameter β increases, the entering *keiretsu* firm shares more of the gain from entry with the *keiretsu* firm that had previously entered, and also shares more of the losses its entry imposes on this firm. Thus the returns to entry for the new *keiretsu* entrant are reduced. To maintain indifference it is necessary then that the *non-keiretsu* firm's probability of entry declines.

For the interesting subgames, the effects of changes in the cost parameters dC^{**} and $d\underline{C}^{**}$ may be explained in a similar manner. As C^{**} increases, the value of entry to the *non-keiretsu* firm declines, so to maintain the indifference condition the entry probability of the appropriate *keiretsu* firm must fall. As $\underline{C}^{**}$ increases the value of entry to the appropriate *keiretsu* firm declines, so to maintain the indifference condition of the mixed strategy equilibrium the entry probability of the *non-keiretsu* firm must fall. Notice also that since $d\rho_3(G_{1,3})/d\beta < 0$ and $d\rho_3(G_{2,3})/d\beta < 0$ and both $\rho_1(G_{1,3}) = \rho_3(G_{1,3})$ and $\rho_2(G_{2,3}) = \rho_3(G_{2,3})$ if $\beta = 0$, each *keiretsu* firm always has a higher probability of FDI than the *non-keiretsu* firm. In the subgame $G_{1,2}$ only *keiretsu* firms remain and only *non-keiretsu* firms have entered. The effects of β on entry probabilities are explained by the dilution of entry incentives as discussed for the other subgames. The effects of $C^{**}$are again determined be the mixed strategy indifference conditions as above. That $\underline{C}^{**}$ does not effect *keiretsu* entry probabilities follows from the fact that the only prior entrant was not a *keiretsu* member and does not share any private cost reducing information.

2.4.3 The First Wave: Entry in the Game $G_{1,2,3}$.

Entry in the first wave, as inspection of figures 1 and 2 might suggest, is very complex, if no firm has entered at a time t then there are 8 possible strategy choices leading to 8 possible subgames. The mixed strategy equilibrium for $G_{1,2,3}$ is characterized by 6 conditions. For each firm n we may define a value for the game and an indifference condition that states the firm is indifferent between FDI and domestic production. For firms 1 or 2 these conditions take the form

$$\begin{aligned}
&\rho_{12}(G_{1,2,3})\left[\rho_3(G_{1,2,3})V^1(FFF \mid G_{1,2,3}) + (1-\rho_3(G_{1,2,3}))V^1(FFD \mid G_{1,2,3})\right] \\
&+(1-\rho_{12}(G_{1,2,3}))\left[\rho_3(G_{1,2,3})V^1(FDF \mid G_{1,2,3}) + (1-\rho_3(G_{1,2,3}))V^1(FDD \mid G_{1,2,3})\right] \\
&= \rho_{12}(G_{1,2,3})\left[\rho_3(G_{1,2,3})V^1(DFF \mid G_{1,2,3}) + (1-\rho_3(G_{1,2,3}))V^1(DFD \mid G_{1,2,3})\right] \\
&+(1-\rho_{12}(G_{1,2,3}))\left[\rho_3(G_{1,2,3})V^1(DDF \mid G_{1,2,3}) + (1-\rho_3(G_{1,2,3}))V^1(DDD \mid G_{1,2,3})\right]
\end{aligned}$$

and

$$V^1(DDD \mid G_{1,2,3}) = \rho_{12}(G_{1,2,3})^2 \left[\rho_3(G_{1,2,3})V^1(FFF \mid G_{1,2,3}) + (1-\rho_3(G_{1,2,3}))V^1(FFD \mid G_{1,2,3})\right]$$

$$+\rho_{12}(G_{1,2,3})(1-\rho_{12}(G_{1,2,3}))\left[\rho_3(G_{1,2,3})V^1(FDF \mid G_{1,2,3}) + (1-\rho_3(G_{1,2,3}))V^1(FDD \mid G_{1,2,3})\right]$$

$$+(1-\rho_{12}(G_{1,2,3}))\rho_{12}(G_{1,2,3})\left[\rho_3(G_{1,2,3})V^1(DFF \mid G_{1,2,3}) + (1-\rho_3(G_{1,2,3}))V^1(DFD \mid G_{1,2,3})\right]$$

$$+(1-\rho_{12}(G_{1,2,3}))^2\left[\rho_3(G_{1,2,3})V^1(DDF \mid G_{1,2,3}) + (1-\rho_3(G_{1,2,3}))V^1(DDD \mid G_{1,2,3})\right]$$

similar conditions hold for firm 3. Substituting in and solving these equations (together with the firm 3 conditions-see appendix 3) yields solutions

$$\rho_1(G_{1,2,3}) = \rho_2(G_{1,2,3}) = \psi(C^*, C^{**}, r, \beta, \Pi^1_{DFF}, \Pi^1_{FDF}, \Pi^1_{FFF})$$

$$\rho_3(G_{1,2,3}) = \chi(C^*, C^{**}, \underline{C}^{**}, r, \beta, \Pi^1_{DFF}, \Pi^1_{FDF}, \Pi^1_{FFF}).$$

Details of the form of these expressions are provided in appendix 3. The solutions are very complex and do not easily yield analytical results, thus we resort to numerical method to explore their properties.

Variations in the Level of Cooperation and Initial Cost of Entry. Tables 3 and 4 provide illustrative examples of simulations run using Mathematica[17].

[17] For the simulation reported we assumed that $\pi_{FDD} = 100$, $\pi_{FDF} = \pi_{FFD} = 96$, $\pi_{FFF} = 90$, $\pi_{DDD} = 89$, $\pi_{DDF} = \pi_{DFD} = 84$, $\pi_{DFF} = 79$, $r = 5\%$.
For variations in the fixed cost of initial entry we maintained the differential betwen initial and subseqent entry costs by imposing the same changes on C^{**} and $\underline{C}^{**}$.
The properties of the results reported were generally not sensitive to variations in parameter values that satisfied the restrictions of the theory.

		Level of Cooperation β					
		0.0	0.1	0.2	0.3	0.4	0.5
Initial Entry Cost C^*as a percentage of $\frac{\Pi^1_{FDD}}{r}$	13	0.798548 0.767037	0.802769 0.646013	0.806623 0.54338	0.810167 0.460451	0.813446 0.388207	0.816497 0.326359
	13.5	0.741582 0.6998	0.746784 0583694	0.751541 0.487346	0.755922 0.407335	0.759982 0.341211	0.763763 0.287216
	14	0.66667 0.583333	0.676945 0.466752	0.685852 0.382626	0.693713 0.320238	0.700746 0.273668	0.707107 0.239369
	14.5	0.589226 0.457293	0.604204 0.353279	0.616748 0.286554	0.62755 0.242181	0.637038 0.213166	0.645497 0.195799
	15	0.5 0.277778	0.521899 0.209411	0.539345 0.174076	0.553894 0.156032	0.566391 0.149584	0.57735 0.152197

Table 3 - First wave entry probabilities for *keiretsu* firms, ρ_{12}, (top cell entry) and *non-keiretsu* firms, ρ_3, (bottom cell entry) for different cooperation β, and initial entry costs C^* parameters.

We see from table 3 that an increase in the level of cooperation, β, between *keiretsu* firms increases the first wave entry probabilities of *keiretsu* firms and lowers the entry probabilities of *non-keiretsu* firms[18]. The intuition behind these results is complex. Changes in β affect the entry probabilities both in the first wave entry game, and the subsequent second wave entry subgames. Recall that in a mixed strategy equilibrium the entry probabilities are determined by the requirement that each firm be indifferent between undertaking FDI and continuing with domestic production. When β increases, the *keiretsu* firms individually find FDI less attractive in each subgame. This is because an entrant shares a greater proportion of the benefits from entry with its *keiretsu* partner, and also shares a greater proportion of the losses its entry imposes on its partner. So to maintain the *keiretsu* firms indifference condition the relative probability of initial entry by the *non-keiretsu* firm must decline. Similarly for the *keiretsu* firms the relative probability of initial entry must increase to keep the *non-keiretsu* firm indifferent between FDI and domestic production. Here the

[18] It might appear that the first column in table 3 for $\beta = 0$ reveals an inconsistency in the results. This is not the case. The simulations were carried out assuming that *keiretsu* firms share all private information (not β percent of it) thus the entry probabilites should only be equal when $\beta = 0$ and $C^{**} - \underline{C}^{**} = 0$. Inspection of table 4 demonstrates that this consistency check is satisfied.

argument is even more complex. Since an increase in β makes the *non-keiretsu* firm less likely to enter in each subsequent subgame (see the next section for details), the relative value of entry to the *non-keiretsu* firm in the initial game thus increases. Hence, to maintain indifference for the *non-keiretsu* firm the relative probability of entry by the *keiretsu* firms must increase.

Increases in initial entry costs lower the probabilities of entry for both *keiretsu* and *non-keiretsu* firms[19]. Here, in equilibrium, both the *keiretsu* firms and the *non-keiretsu* firm must have lower entry probabilities if they are to remain indifferent between FDI and continued domestic production.

Variations in the Level of Cooperation and the Value of Private Information. Table 4 characterizes our simulation results for variations in the value of private information, or $C^{**} - \underline{C}^{**}$.

		Level of Cooperation β					
		0.0	0.1	0.2	0.3	0.4	0.5
Value of private	0.0	0.66667 0.66667	0.676945 0.547127	0.685852 0.449485	0.693713 0.367889	0.700746 0.298665	0.707107 0.239369
information	1.0	0.66667 0.645833	0.676945 0.526354	0.685852 0.431788	0.693713 0.35505	0.700746 0.291839	0.707107 0.239369
$C^{**} - \underline{C}^{**}$	2.0	0.66667 0.625	0.676945 0.506044	0.685852 0.414771	0.693713 0.34286	0.700746 0.285421	0.707107 0.239369
as a percentage	3.0	0.66667 0.604167	0.676945 0.486181	0.685852 0.398395	0.693713 0.33127	0.700746 0.279374	0.707107 0.239369
of $\frac{\Pi^1_{FDD}}{r}$	4.0	0.66667 0.58333	0.676945 0.466752	0.685852 0.382626	0.693713 0.320238	0.700746 0.273668	0.707107 0.239369

Table 4 - First wave entry probabilities for *keiretsu* firms (top cell entry), ρ_{12}, and *non-keiretsu* firms (bottom cell entry), ρ_3, for different levels of cooperation, β, and private information values, $C^{**} - \underline{C}^{**}$.

[19] These results obtained for "almost all" the parameter space. For high costs of initial entry, such that the probability of entry by *keiretsu* firms became very small (in the neighborhood of $\rho_{12} \to 0.001$), the entry probabilities for the *non- keiretsu* firms became "eratic" . We believe this reflects a highly sensitive trade-off, as the *keiretsu* firm's entry probabilities become very small there is a significant incentive for the *non-keiretsu* firm to enter, but at the same time the high costs that induced this behavior from the *keiretsu* firms also provides a strong disincentive to entry for the *non-keiretsu* firm.

Despite their apparent complexity the properties of the equilibria may be quite easily stated. Increases in the value of private information $C^{**} - \underline{C}^{**}$, generated by varying $\underline{C}^{**}$ for a given C^{**}, lower the probability of entry by *non-keiretsu* firms at all levels of the cooperation parameter, and do not affect the probability of entry by the *keiretsu* firms. Here again the intuition is subtle and follows from understanding the nature of a mixed strategy equilibrium. An increase in $C^{**} - \underline{C}^{**}$ makes it more attractive for each *keiretsu* firm to delay initial entry in anticipation that the other will enter and provide them with this reduction in entry cost. Thus, for the *keiretsu* firms to remain indifferent between FDI and domestic production the relative probability of entry by the *non-keiretsu* firm must fall. The invariance of the *keiretsu* firm's entry probabilities arises because variations in $\underline{C}^{**}$ do not affect the payoffs associated with FDI for the *non-keiretsu* firm. Since the probabilities of entry by the *keiretsu* firms are determined by the condition that the *non-keiretsu* firm is indifferent between FDI and domestic production it then follows that the probability of entry by the *keiretsu* firms is unaffected by variations in $\underline{C}^{**}$.[20] Notice also that for all values of $\beta > 0$ and $C^{**} - \underline{C}^{**}$ the probability of entry by each *keiretsu* firm is larger than for the *non-keiretsu* firm. Our results are illustrated in figure 3

[20] The results reported were found to be very robust and obtained over all of the parameter space for which mixed strategy equilibria were found to exist. Full details and the simulation programs are available from the authors on request.

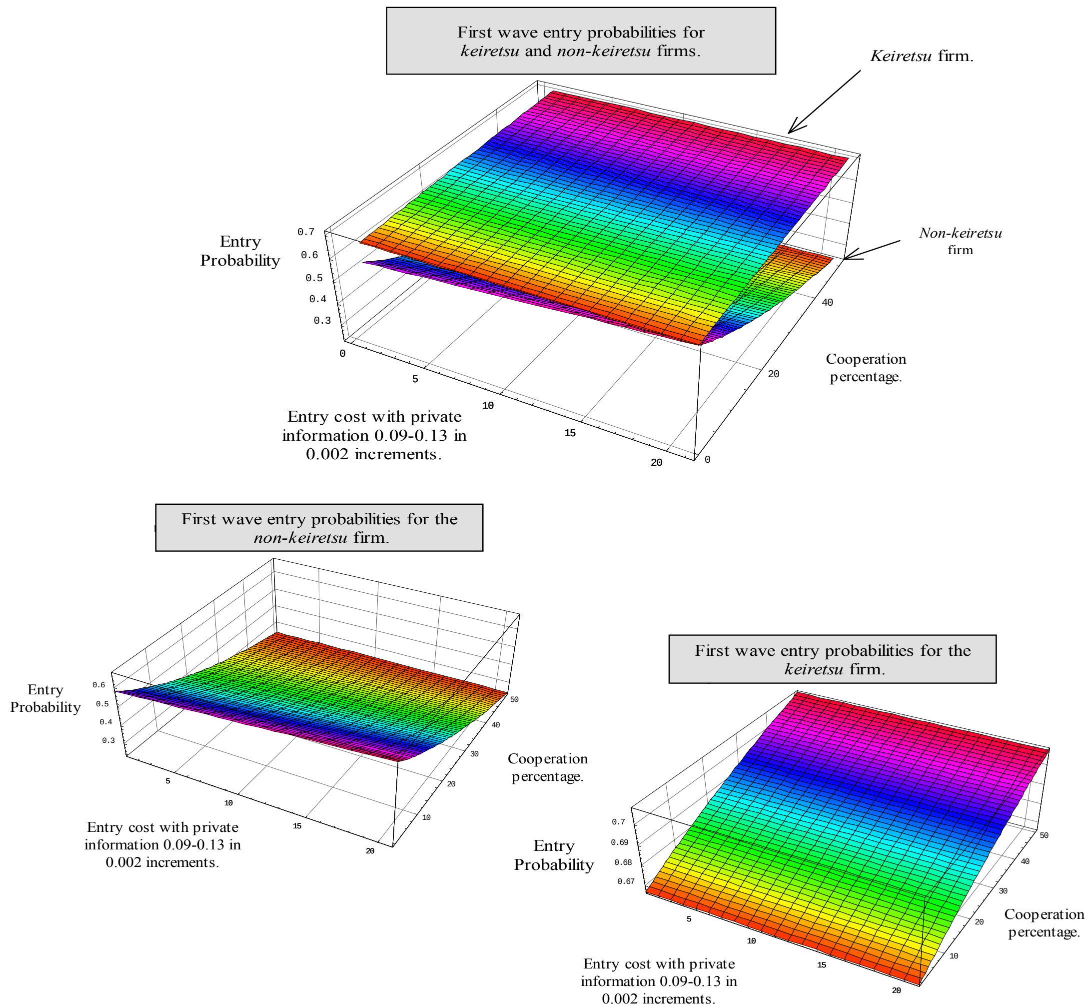
First wave entry probabilities for *keiretsu* and *non-keiretsu* firms.
Keiretsu firm.
Non-keiretsu firm
Entry Probability
0.7
0.6
0.5
0.4
0.3
0
5
10
15
20
Entry cost with private information 0.09-0.13 in 0.002 increments.
0
20
40
Cooperation percentage.
First wave entry probabilities for the *non-keiretsu* firm.
Entry Probability
0.6
0.5
0.4
0.3
5
10
15
20
Entry cost with private information 0.09-0.13 in 0.002 increments.
10
20
30
40
50
Cooperation percentage.
First wave entry probabilities for the *keiretsu* firm.
Entry Probability
0.7
0.69
0.68
0.67
5
10
15
20
Entry cost with private information 0.09-0.13 in 0.002 increments.
10
20
30
40
50
Cooperation percentage.

Figure 3.

3 Conclusions.

In this paper we have explored how the existence of cooperative industrial groupings such as Japanese *keiretsu* or Korean *chaebol* may effect the likelihood of FDI. This question has been addressed before in the context of a two firm model in which it was found that cooperation dilutes the incentives for FDI. Here we allowed for three firms, two of which are members of a cooperative industrial grouping. This allowed two significant innovations. We were able to explore FDI entry probabilities amongst a population of firms some of which are cooperative and some independent. Further, we modeled asymmetric information by assuming that *keiretsu* firms share all pertinent information with fellow group members, whereas independent firms only reveal that which is publicly observable. Our results contrast strikingly with those of the two firm model (see the subgame $G_{1,2}$ in table 2 or Ellis and Fausten [4]). In the presence of a heterogeneous pool of firms, and with the information asymmetries just described, cooperation tends to increase the incentives for FDI.

Despite the complexity of the analysis, the detailed conclusions of our model are quite clear. For any given informational advantage, $\overline{C}^{**} - \underline{C}^{**}$, in each subgame involving both *keiretsu* and *non-keiretsu* firms, the *keiretsu* firms undertake FDI with higher probability. Further, in these subgames, the more cooperative are the *keiretsu* firms, as characterized by the cooperation parameter β, the greater the margin by which their entry probabilities exceed those of *non-keiretsu* firms. The effects of an informational advantage are also clear. In the initial game, termed the first wave, the *non-keiretsu* firm is discouraged from entry by the informational advantage of the two *keiretsu* firms (as $\overline{C}^{**} - \underline{C}^{**}$ increases, $\rho_3(G_{1,2,3})$ falls). The entry probabilities of the *keiretsu* firms are unaffected. In the subgames termed the second wave, the effects are somewhat different, an increase in the informational advantage *raises* the entry probability of the *non-keiretsu* firm, relative to the entry probabilities of *keiretsu* firms.

This model provides some potentially interesting policy prescriptions. Jurisdictions interested in attracting inward FDI frequently offer direct financial incentives in the form of tax breaks, and indirect incentives in the form of services and infrastructure that facilitate the transition of production to their locations. In the first wave we may view both types of incentive as lowering the entry cost parameter C^*[21]. As table 3 indicates, both *keiretsu* and *non-keiretsu* firms respond positively to this incentive. However, careful reading of table 3 reveals that the marginal effect of this incentive on *keiretsu* firm entry probabilities is decreasing in the level of cooperation between the group member firms. In fact at low levels of cooperation they are more responsive to these FDI incentives than the *non-keiretsu* firm, while at high levels of cooperation the converse is true.

In the second wave tax breaks may be viewed as generating reductions in C^{**} and $\underline{C}^{**}$. If the host jurisdiction is limited to giving firms equal tax treatment, then we can see from table 1 that equal reductions in C^{**} and $\underline{C}^{**}$ will increase the entry probabilities of both *keiretsu* and *non-keiretsu* firms. Further, in the second wave subgames involving both *keiretsu* and *non-keiretsu* firms, a tax cut has a greater effect at the margin on the entry probability of a *keiretsu* firm. If, alternatively, jurisdictions have the ability to offer firm-specific tax breaks then inspection of table 1 reveals an interesting asymmetry, tax cuts are more effective at the margin in attracting *keiretsu* firms. But a potential host jurisdiction is best advised to spend tax dollars in reducing C^{**} the entry cost of the *non-keiretsu* firm, because this makes the *keiretsu* firms more likely to enter. Clearly jurisdictions need to be careful in designing tax incentive schemes in these strategic environments.

[21] By modeling tax incentives in this fashion we are consistent with both the cost reduction capturing a permanent tax break, so the reduction in C^*must be thought of in PDV terms, or, as representing a tax holiday, where the reduction in C^* is temporary.

4 Appendices.

4.1 Appendix 1 - Derivation of the value functions for the sub-games G_1, G_2,and G_3.

We derive the value functions $V^3(FFF \mid G_3)$ and $V^3(DFF \mid G_3)$, $V^1(FFF \mid G_1)$, $V^1(DFF \mid G_1)$, and $V^2(FFF \mid G_2)$, $V^2(DFF \mid G_2)$ may be obtained in an identical fashion.

$$V^3(FFF \mid G_3) \equiv \int_{t=0}^{\infty} \left[(1 - \sum_{i=1,2} \beta_3^i) \left[\Pi_{FFF}^3 - \ K^{***} \right] + \beta_1^3 \Pi_{FFF}^1 + \beta_2^3 \Pi_{FFF}^2 \right] e^{-rt} dt$$

integrating the RHS of this expression gives us

$$V^3(FFF \mid G_3) \equiv (1 - \sum_{i=1,2} \beta_3^i) \left[\frac{\Pi_{FFF}^3}{r} - \ K^{***} \right] + \beta_1^3 \frac{\Pi_{FFF}^1}{r} + \beta_2^3 \frac{\Pi_{FFF}^2}{r}$$

where $K^{***} = C^{***}$ or $\underline{C}^{***}$as appropriate.

$$\begin{aligned} V^3(DFF \mid G_3) &\equiv \int_{t=0}^{\infty} \left[(1 - \sum_{i=1,2} \beta_3^i) \Pi_{DFF}^3 + \beta_1^3 \Pi_{FFD}^1 + \beta_2^3 \Pi_{FDF}^2 \right] e^{-rt} dt \\ &= (1 - \sum_{i=1,2} \beta_3^i) \frac{\Pi_{DFF}^3}{r} + \beta_1^3 \frac{\Pi_{FFD}^1}{r} + \beta_2^3 \frac{\Pi_{FDF}^2}{r} \end{aligned}$$

4.2 Appendix 2 - Derivation of the Equilibrium Mixed Strategy Entry Probabilities for the Subgames $G_{1,2}$, $G_{2,3}$, and $G_{1,3}$.

4.2.1 Subgame $G_{1,2}$.

For this subgame we utilize the expressions for the value of the (sub)game and the indifference conditions to solve for the entry probabilities as

$$\rho_{12}(G_{1,2})V^1(FFF \mid G_{1,2}) + (1-\rho_{12}(G_{1,2}))V^1(FDF \mid G_{1,2})$$
$$= \rho_{12}(G_{1,2})V^1(DFF \mid G_{1,2}) + (1-\rho_{12}(G_{1,2}))V^1(DDF \mid G_{1,2})$$

and

$$V^1(DDF \mid G_{1,2}) = \rho_{12}(G_{1,2})^2 V^1(FFF \mid G_{1,2})) + \rho_{12}(G_{1,2})(1-\rho_{12}(G_{1,2}))V^1(FDF \mid G_{1,2})$$
$$+(1-\rho_{12}(G_{1,2}))\rho_{12}(G_{1,2})V^1(DFF \mid G_{1,2}) + (1-\rho_{12}(G_{1,2}))^2 V^1(DDF \mid G_{1,2})$$

Multiplying through the indifference condition by $\rho_{12}(G_{1,2})$ then manipulating the two expressions reveals

$$V^1(DFF \mid G_{1,2}) = V^1(DDF \mid G_{1,2})$$

substituting this back into the indifference condition and solving provides

$$\rho_{12}(G_{1,2}) = \frac{V^1(DFF \mid G_{1,2}) - V^1(FDF \mid G_{1,2})}{V^1(FFF \mid G_{1,2}) - V^1(FDF \mid G_{1,2})}$$

substituting in for the terms

$$V^1(DFF \mid G_{1,2}) = (1-\beta)\frac{\Pi^1_{DFF}}{r} + \beta\left(\frac{\Pi^2_{FFD}}{r} - C^{**}\right) = (1-\beta)\frac{\Pi^1_{DFF}}{r} + \beta\left(\frac{\Pi^1_{FDF}}{r} - C^{**}\right)$$

$$V^1(FDF \mid G_{1,2}) = (1-\beta)\left(\frac{\Pi^1_{FDF}}{r} - C^{**}\right) + \beta\frac{\Pi^2_{DFF}}{r} = (1-\beta)\left(\frac{\Pi^1_{FDF}}{r} - C^{**}\right) + \beta\frac{\Pi^1_{DFF}}{r}$$

and

$$V^1(FFF \mid G_{1,2}) = (1-\beta)\left(\frac{\Pi^1_{FFF}}{r} - C^{**}\right) + \beta\left(\frac{\Pi^2_{FFF}}{r} - C^{**}\right) = \frac{\Pi^1_{FFF}}{r} - \underline{C}^{**}$$

provides

$$\rho_{12}(G_{1,2}) = \frac{(1-2\beta)\left(\frac{\Pi^1_{DFF}}{r} - \frac{\Pi^1_{FDF}}{r} + C^{**}\right)}{\frac{\Pi^2_{FFF}}{r} - (1-\beta)\frac{\Pi^1_{FDF}}{r} - \beta\frac{\Pi^1_{DFF}}{r} - \beta C^{**}}$$

as reported in the text.

4.2.2 Subgame $G_{2,3}$.

$>$From the text we have the equations for the values of the game

$$V^2(DDF \mid G_{2,3}) = \rho_2(G_{2,3})\rho_3(G_{2,3})V^2(FFF \mid G_{2,3})) + \rho_2(G_{2,3})(1-\rho_3(G_{2,3}))V^2(FDF \mid G_{2,3})$$
$$+(1-\rho_2(G_{2,3}))\rho_3(G_{2,3})V^2(DFF \mid G_{2,3}) + (1-\rho_2(G_{2,3}))(1-\rho_3(G_{2,3}))V^2(DDF \mid G_{2,3})$$

$$V^3(DFD \mid G_{2,3}) = \rho_2(G_{2,3})\rho_3(G_{2,3})V^3(FFF \mid G_{2,3})) + \rho_3(G_{2,3})(1-\rho_2(G_{2,3}))V^3(FFD \mid G_{2,3})$$
$$+(1-\rho_3(G_{2,3}))\rho_3(G_{2,3})V^3(DFF \mid G_{2,3}) + (1-\rho_3(G_{2,3}))(1-\rho_2(G_{2,3}))V^3(DFD \mid G_{2,3})$$

and the indifference conditions

$$\begin{aligned}\rho_2(G_{2,3})V^3(FFF \quad &\mid \quad G_{2,3}) + (1-\rho_2(G_{2,3}))V^3(FFD \mid G_{2,3})\\ &= \quad \rho_2(G_{2,3})V^3(DFF \mid G_{2,3}) + (1-\rho_2(G_{2,3}))V^3(DFD \mid G_{2,3})\end{aligned}$$

$$\rho_3(G_{2,3})V^2(FFF \mid G_{2,3}) + (1-\rho_3(G_{2,3}))V^2(FDF \mid G_{2,3})$$

$$= \rho_3(G_{2,3})V^2(DFF \mid G_{2,3}) + (1-\rho_3(G_{2,3}))V^2(DDF \mid G_{2,3})$$

multiplying the indifference conditions by $\rho_3(G_{2,3})$ and $\rho_2(G_{2,3})\rho_2(G_{2,3})$ respectively yields

$$\rho_3(G_{2,3})\rho_2(G_{2,3})V^3(FFF \mid G_{2,3}) + \rho_3(G_{2,3})(1-\rho_2(G_{2,3}))V^3(FFD \mid G_{2,3})$$

$$= \rho_3(G_{2,3})\rho_2(G_{2,3})V^3(DFF \mid G_{2,3}) + \rho_3(G_{2,3})(1-\rho_2(G_{2,3}))V^3(DFD \mid G_{2,3})$$

$$\rho_2(G_{2,3})\rho_3(G_{2,3})V^2(FFF \mid G_{2,3}) + \rho_2(G_{2,3})(1-\rho_3(G_{2,3}))V^2(FDF \mid G_{2,3})$$

$$= \rho_2(G_{2,3})\rho_3(G_{2,3})V^2(DFF \mid G_{2,3}) + \rho_2(G_{2,3})(1-\rho_3(G_{2,3}))V^2(DDF \mid G_{2,3})$$

substitution the RHS of these expressions into the values of the game gives

$$V^2(DDF \mid G_{2,3}) = \rho_2(G_{2,3})\rho_3(G_{2,3})V^2(DFF \mid G_{2,3}) + \rho_2(G_{2,3})(1-\rho_3(G_{2,3}))V^2(DDF \mid G_{2,3})$$

$$+(1-\rho_2(G_{2,3}))\rho_3(G_{2,3})V^2(DFF \mid G_{2,3}) + (1-\rho_2(G_{2,3}))(1-\rho_3(G_{2,3}))V^2(DDF \mid G_{2,3})$$

$$V^3(DFD \mid G_{2,3}) = \rho_3(G_{2,3})\rho_2(G_{2,3})V^3(DFF \mid G_{2,3}) + \rho_3(G_{2,3})(1-\rho_2(G_{2,3}))V^3(DFD \mid G_{2,3})$$

$$+(1-\rho_3(G_{2,3}))\rho_3(G_{2,3})V^3(DFF \mid G_{2,3}) + (1-\rho_3(G_{2,3}))(1-\rho_2(G_{2,3}))V^3(DFD \mid G_{2,3})$$

simplifying these reduce to

$$V^2(DDF \mid G_{2,3}) = V^2(DFF \mid G_{2,3})$$

$$V^3(DFD \mid G_{2,3}) = V^3(DFF \mid G_{2,3})$$

using this information the indifference conditions may be rewritten

$$\rho_3(G_{2,3})V^2(FFF \mid G_{2,3}) + (1-\rho_3(G_{2,3}))V^2(FDF \mid G_{2,3})$$
$$= \rho_3(G_{2,3})V^2(DFF \mid G_{2,3}) + (1-\rho_3(G_{2,3}))V^2(DFF \mid G_{2,3})$$

$$\rho_2(G_{2,3})V^3(FFF \mid G_{2,3}) + (1-\rho_2(G_{2,3}))V^3(FFD \mid G_{2,3})$$
$$= \rho_2(G_{2,3})V^3(DFF \mid G_{2,3}) + (1-\rho_2(G_{2,3}))V^3(DFF \mid G_{2,3})$$

rewriting these in terms of $\rho_2(G_{2,3})$ and $\rho_3(G_{2,3})$ gives

$$\rho_2(G_{2,3}) = \frac{V^3(DFF \mid G_{2,3}) - V^3(FFD \mid G_{2,3})}{V^3(FFF \mid G_{2,3}) - V^3(FFD \mid G_{2,3}))}$$

$$\rho_3(G_{2,3}) = \frac{V^2(DFF \mid G_{2,3}) - V^2(FDF \mid G_{2,3})}{V^2(FFF \mid G_{2,3}) - V^2(FDF \mid G_{2,3}))}$$

now

- $V^3(DFF \mid G_{2,3}) = \frac{\Pi^3_{DFF}}{r}$,
- $V^3(FFD \mid G_{2,3}) = \frac{\Pi^3_{FFD}}{r} - C^{**}$,and
- $V^3(FFF \mid G_{2,3}) = \frac{\Pi^3_{FFF}}{r} - C^{**}$, so

$$\rho_2(G_{2,3}) = \frac{\frac{\Pi^3_{DFF}}{r} - \frac{\Pi^3_{FFD}}{r} + C^{**}}{\frac{\Pi^3_{FFF}}{r} - C^{**} - \frac{\Pi^3_{FFD}}{r} + C^{**}} = \frac{\Pi^3_{DFF} - \Pi^3_{FFD} + rC^{**}}{\Pi^3_{FFF} - \Pi^3_{FFD}}$$

further

- $V^2(DFF \mid G_{2,3}) = (1-\beta)\frac{\Pi^2_{DFF}}{r} + \beta\frac{\Pi^1_{FDF}}{r}$,
- $V^2(FDF \mid G_{2,3}) = (1-\beta)\left[\frac{\Pi^2_{FDF}}{r} - \underline{C}^{**}\right] + \beta\frac{\Pi^1_{FFD}}{r}$, and

- $V^2(FFF \mid G_{2,3}) = \frac{\Pi^3_{FFF}}{r} - \underline{C}^{**}$ so

$$\begin{aligned}
\rho_3(G_{2,3}) &= \frac{V^2(DFF \mid G_{2,3}) - V^2(FDF \mid G_{2,3})}{V^2(FFF \mid G_{2,3}) - V^2(FDF \mid G_{2,3})} \\
&= \frac{(1-\beta)\frac{\Pi^2_{DFF}}{r} + \beta\frac{\Pi^1_{FDF}}{r} - (1-\beta)\left[\frac{\Pi^2_{FDF}}{r} - \underline{C}^{**}\right] - \beta\frac{\Pi^1_{FFD}}{r}}{\frac{\Pi^2_{FFF}}{r} - (1-\beta)C^{**} - (1-\beta)\left[\frac{\Pi^2_{FDF}}{r} - \underline{C}^{**}\right] - \beta\frac{\Pi^1_{FFD}}{r}} \\
&= \frac{(1-\beta)\left(\frac{\Pi^1_{DFF}}{r} - \frac{\Pi^1_{FDF}}{r} + \underline{C}^{**}\right)}{\frac{\Pi^1_{FFF}}{r} - \frac{\Pi^1_{FDF}}{r}}
\end{aligned}$$

which are the solutions reported in the text.

4.2.3 Subgame $G_{1,3}$.

The solutions for this subgame are derived exactly as in the previous case except firms 2 and 1 change roles, we immediately have

$$\rho_1(G_{1,3}) = \frac{\frac{\Pi^3_{DFF}}{r} - \frac{\Pi^3_{FFD}}{r} + C^{**}}{\frac{\Pi^3_{FFF}}{r} - C^{**} - \frac{\Pi^3_{FFD}}{r} + C^{**}} = \frac{\Pi^3_{DFF} - \Pi^3_{FFD} + rC^{**}}{\Pi^3_{FFF} - \Pi^3_{FFD}}$$

$$\rho_3(G_{1,3}) = \frac{(1-\beta)\left(\frac{\Pi^1_{DFF}}{r} - \frac{\Pi^1_{FDF}}{r} + \underline{C}^{**}\right)}{\frac{\Pi^1_{FFF}}{r} - \frac{\Pi^1_{FDF}}{r}}$$

4.3 Appendix 3 - Derivation of the Equilibrium Mixed Strategy Entry Probabilities for the Game $G_{1,2,3}$.

Exploiting symmetry so $\rho_{12}(G_{1,2,3}) \equiv \rho_1(G_{1,2,3}) = \rho_2(G_{1,2,3}) \neq \rho_3(G_{1,2,3})$, we adopt the same method as used in appendix 2 to obtain solution equations for $\rho_{12}(G_{1,2,3})$ and $\rho_3(G_{1,2,3})$ of the form

$$(2-\rho_{12}(G_{1,2,3}))\,\rho_{12}(G_{1,2,3})^2V^3(FFF \mid G_{1,2,3})$$

$$+2\,(2-\rho_{12}(G_{1,2,3}))\,\rho_{12}(G_{1,2,3})(1-\rho_{12}(G_{1,2,3}))V^3(FFD \mid G_{1,2,3})$$

$$+\,(2-\rho_{12}(G_{1,2,3}))\,(1-\rho_{12}(G_{1,2,3}))^2V^3(FDD \mid G_{1,2,3})$$

$$-\rho_{12}(G_{1,2,3})V^3(DFF \mid G_{1,2,3})-2(1-\rho_{12}(G_{1,2,3}))V^3(DFD \mid G_{1,2,3})=0$$

$$V^1(FFF \mid G_{1,2,3})\rho_{12}(G_{1,2,3})\rho_3(G_{1,2,3})\,[\rho_{12}(G_{1,2,3})\rho_3(G_{1,2,3})-\rho_{12}(G_{1,2,3})-\rho_3(G_{1,2,3})]$$

$$+V^1(FFD \mid G_{1,2,3})\rho_{12}(G_{1,2,3})\,[1-\rho_3(G_{1,2,3})]\,[\rho_{12}(G_{1,2,3})\rho_3(G_{1,2,3})-\rho_{12}(G_{1,2,3})-\rho_3(G_{1,2,3})]$$

$$+V^1(FDF \mid G_{1,2,3})\,[1-\rho_{12}(G_{1,2,3}])\rho_3(G_{1,2,3})\,[\rho_{12}(G_{1,2,3})\rho_3(G_{1,2,3})-\rho_{12}(G_{1,2,3})-\rho_3(G_{1,2,3})]$$

$$+V^1(FDD \mid G_{1,2,3})\,[1-\rho_{12}(G_{1,2,3})]\,[1-\rho_3(G_{1,2,3})]\,[\rho_{12}(G_{1,2,3})\rho_3(G_{1,2,3})-\rho_{12}(G_{1,2,3})-\rho_3(G_{1,2,3})]$$

$$+V^1(DFF \mid G_{1,2,3})\rho_{12}(G_{1,2,3})\rho_3(G_{1,2,3})+V^1(DFD \mid G_{1,2,3})\rho_{12}(G_{1,2,3})\,[1-\rho_3(G_{1,2,3})]$$

$$+V^1(DDF \mid G_{1,2,3})\,[1-\rho_{12}(G_{1,2,3})]\,\rho_3(G_{1,2,3})=0$$

We Derive first the expression for $\rho_{12}(G_{1,2,3})$ and thus need to obtain expressions for

- $V^3(FFF \mid G_{1,2,3})=\frac{\Pi^3_{FFF}}{r}-C^*$
- $V^3(FFD \mid G_{1,2,3})=\frac{\Pi^3_{FFD}}{r}-C^*$
- $V^3(FDD \mid G_{1,2,3})=V^3(FDD \mid G_{1,2})-C^*$
- $V^3(DFF \mid G_{1,2,3})=\frac{\Pi^3_{DFF}}{r}$
- $V^3(DFD \mid G_{1,2,3})=V^3(DFD \mid G_{2,3})$

It now follows that we need to obtain $V^3(FDD \mid G_{1,2})$ and $V^3(DFD \mid G_{2,3})$ from the appropriate subgames

The subgame $V^3(FDD \mid G_{1,2})$

the value to player 3 of this subgame may be written

$$V^3(FDD \mid G_{1,2}) = \rho_1(G_{1,2})\rho_2(G_{1,2})V^3(FFF \mid G_{1,2}))$$

$$+\rho_1(G_{1,2})(1-\rho_2(G_{1,2}))V^3(FFD \mid G_{1,2})$$

$$+(1-\rho_1(G_{1,2}))\rho_2(G_{1,2})V^3(FDF \mid G_{1,2})$$

$$+(1-\rho_1(G_{1,2}))(1-\rho_2(G_{1,2}))V^3(FDD \mid G_{1,2})$$

exploiting symmetry and $V^3(FFD \mid G_{1,2}) = V^3(FDF \mid G_{1,2})$ this reduces to

$$V^3(FDD \mid G_{1,2}) = \frac{\rho_{12}(G_{1,2})V^3(FFF \mid G_{1,2})) + 2(1-\rho_{12}(G_{1,2}))V^3(FFD \mid G_{1,2})}{2-\rho_{12}(G_{1,2})}$$

now

- $V^3(FFF \mid G_{1,2}) = \frac{\Pi^3_{FFF}}{r}$
- $V^3(FFD \mid G_{1,2}) = \frac{\Pi^3_{FFD}}{r}$,so

$$V^3(FDD \mid G_{1,2}) = \frac{\rho_{12}(G_{1,2})\frac{\Pi^3_{FFF}}{r} + 2(1-\rho_{12}(G_{1,2}))\frac{\Pi^3_{FFD}}{r}}{2-\rho_{12}(G_{1,2})}$$

from appendix 2 we have

$$\rho_{12}(G_{1,2}) = \frac{(1-2\beta)\left(\frac{\Pi^1_{DFF}}{r} - \frac{\Pi^1_{FDF}}{r} + C^{**}\right)}{\frac{\Pi^2_{FFF}}{r} - (1-\beta)\frac{\Pi^1_{FDF}}{r} - \beta\frac{\Pi^1_{DFF}}{r} - \beta C^{**}}$$

We may now conclude that

$$V^3(FDD \mid G_{1,2}) = \frac{\left(\frac{(1-2\beta)\left(\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FDF}}{r}+C^{**}\right)}{\frac{\Pi^2_{FFF}}{r}-(1-\beta)\frac{\Pi^1_{FDF}}{r}-\beta\frac{\Pi^1_{DFF}}{r}-\beta C^{**}}\right)\frac{\Pi^3_{FFF}}{r}}{2-\left(\frac{(1-2\beta)\left(\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FDF}}{r}+C^{**}\right)}{\frac{\Pi^2_{FFF}}{r}-(1-\beta)\frac{\Pi^1_{FDF}}{r}-\beta\frac{\Pi^1_{DFF}}{r}-\beta C^{**}}\right)}$$

$$+\frac{2\left[1-\left(\frac{(1-2\beta)\left(\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FDF}}{r}+C^{**}\right)}{\frac{\Pi^2_{FFF}}{r}-(1-\beta)\frac{\Pi^1_{FDF}}{r}-\beta\frac{\Pi^1_{DFF}}{r}-\beta C^{**}}\right)\right]\frac{\Pi^3_{FFD}}{r}}{2-\left(\frac{(1-2\beta)\left(\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FDF}}{r}+C^{**}\right)}{\frac{\Pi^2_{FFF}}{r}-(1-\beta)\frac{\Pi^1_{FDF}}{r}-\beta\frac{\Pi^1_{DFF}}{r}-\beta C^{**}}\right)}$$

$$=\frac{\left(\frac{(1-2\beta)\left(\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FDF}}{r}+C^{**}\right)}{\frac{\Pi^2_{FFF}}{r}-(1-\beta)\frac{\Pi^1_{FDF}}{r}-\beta\frac{\Pi^1_{DFF}}{r}-\beta C^{**}}\right)\frac{\Pi^1_{FFF}}{r}}{2-\left(\frac{(1-2\beta)\left(\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FDF}}{r}+C^{**}\right)}{\frac{\Pi^2_{FFF}}{r}-(1-\beta)\frac{\Pi^1_{FDF}}{r}-\beta\frac{\Pi^1_{DFF}}{r}-\beta C^{**}}\right)}$$

$$+\frac{2\left[1-\left(\frac{(1-2\beta)\left(\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FDF}}{r}+C^{**}\right)}{\frac{\Pi^2_{FFF}}{r}-(1-\beta)\frac{\Pi^1_{FDF}}{r}-\beta\frac{\Pi^1_{DFF}}{r}-\beta C^{**}}\right)\right]\frac{\Pi^1_{FDF}}{r}}{2-\left(\frac{(1-2\beta)\left(\frac{\Pi^1_{DFF}}{r}-\frac{\Pi^1_{FDF}}{r}+C^{**}\right)}{\frac{\Pi^2_{FFF}}{r}-(1-\beta)\frac{\Pi^1_{FDF}}{r}-\beta\frac{\Pi^1_{DFF}}{r}-\beta C^{**}}\right)}$$

The same techniques yield

$$V^3(DFD \mid G_{2,3}) = V^3(DFF \mid G_{2,3})$$

and again from appendix 2 we have

$$\rho_2(G_{2,3}) = \frac{\frac{\Pi^3_{DFF}}{r} - \frac{\Pi^3_{FFD}}{r} + C^{**}}{\frac{\Pi^3_{FFF}}{r} - C^{**} - \frac{\Pi^3_{FFD}}{r} + C^{**}}$$

and

$$\rho_3(G_{2,3}) = \frac{(1-\beta)\left(\frac{\Pi^1_{DFF}}{r} - \frac{\Pi^1_{FDF}}{r} + \underline{C}^{**}\right)}{\frac{\Pi^1_{FFF}}{r} - \frac{\Pi^1_{FDF}}{r}}$$

thus we have all the components reported in the text and used in the numerical simulations.

Now we may derive the expression for $\rho_3(G_{1,2,3})$ >From our prior calculations we have

$$V^1(FFF \mid G_{1,2,3})\rho_{12}(G_{1,2,3})\rho_3(G_{1,2,3})\left[\rho_{12}(G_{1,2,3})\rho_3(G_{1,2,3}) - \rho_{12}(G_{1,2,3}) - \rho_3(G_{1,2,3})\right]$$

$$+V^1(FFD \mid G_{1,2,3})\rho_{12}(G_{1,2,3})\left[1-\rho_3(G_{1,2,3})\right]\left[\rho_{12}(G_{1,2,3})\rho_3(G_{1,2,3}) - \rho_{12}(G_{1,2,3}) - \rho_3(G_{1,2,3})\right]$$

$$+V^1(FDF \mid G_{1,2,3})\left[1-\rho_{12}(G_{1,2,3}])\rho_3(G_{1,2,3})\left[\rho_{12}(G_{1,2,3})\rho_3(G_{1,2,3}) - \rho_{12}(G_{1,2,3}) - \rho_3(G_{1,2,3})\right]$$

$$+V^1(FDD \mid G_{1,2,3})\left[1-\rho_{12}(G_{1,2,3})\right]\left[1-\rho_3(G_{1,2,3})\right]\left[\rho_{12}(G_{1,2,3})\rho_3(G_{1,2,3}) - \rho_{12}(G_{1,2,3}) - \rho_3(G_{1,2,3})\right]$$

$$+V^1(DFF \mid G_{1,2,3})\rho_{12}(G_{1,2,3})\rho_3(G_{1,2,3}) + V^1(DFD \mid G_{1,2,3})\rho_{12}(G_{1,2,3})\left[1-\rho_3(G_{1,2,3})\right]$$

$$+V^1(DDF \mid G_{1,2,3})\left[1-\rho_{12}(G_{1,2,3})\right]\rho_3(G_{1,2,3}) = 0$$

so we need expressions for

- $V^1(FFF \mid G_{1,2,3}) = (1-\beta)\left(\frac{\Pi^1_{FFF}}{r} - C^*\right) + \beta\left(\frac{\Pi^2_{FFF}}{r} - C^*\right) = \frac{\Pi^1_{FFF}}{r} - C^*$
- $V^1(FFD \mid G_{1,2,3}) = (1-\beta)\left(\frac{\Pi^1_{FFD}}{r} - C^*\right) + \beta\left(\frac{\Pi^2_{FDF}}{r} - C^*\right) = \frac{\Pi^1_{FFD}}{r} - C^*$
- $V^1(FDF \mid G_{1,2,3}) = (1-\beta)\left(\frac{\Pi^1_{FDF}}{r} - C^*\right) + \beta\frac{\Pi^2_{DFF}}{r}$
- $V^1(FDD \mid G_{1,2,3}) = V^1(FDD \mid G_{2,3}) - (1-\beta)C^*$
- $V^1(DFF \mid G_{1,2,3}) = (1-\beta)\frac{\Pi^1_{DFF}}{r} + \beta\left(\frac{\Pi^2_{FFD}}{r} - C^*\right) = (1-\beta)\frac{\Pi^1_{DFF}}{r} + \beta\left(\frac{\Pi^1_{FDF}}{r} - C^*\right)$
- $V^1(DFD \mid G_{1,2,3}) = V^1(DFD \mid G_{1,3}) - (1-\beta)C^*$
- $V^1(DDF \mid G_{1,2,3}) = V^1(DDF \mid G_{1,2})$

So we need to solve for the values of subgames $V^1(FDD \mid G_{2,3})$, $V^1(DFD \mid G_{1,3})$, and $V^1(DDF \mid G_{1,2})$

The subgame $G_{2,3}$ >From prior calculations we have

$$\rho_2(G_{2,3}) = \frac{\Pi^3_{DFF} - \Pi^3_{FFD} + rC^{**}}{\Pi^3_{FFF} - \Pi^3_{FFD}}$$

$$\rho_3(G_{2,3}) = \frac{(1-\beta)\left(\frac{\Pi^1_{DFF}}{r} - \frac{\Pi^1_{FDF}}{r} + \underline{C}^{**}\right)}{\frac{\Pi^1_{FFF}}{r} - \frac{\Pi^1_{FDF}}{r}}$$

so

$$\begin{aligned}
V^1(FDD \mid G_{1,2,3}) &= V^1(FDD \mid G_{2,3}) - (1-\beta)C^* \\
&= \left[\frac{\rho_2(G_{2,3})\rho_3(G_{2,3})}{1-[1-\rho_2(G_{2,3})]\,[1-\rho_3(G_{2,3})]}\right]\left[\frac{\Pi^1_{FFF}}{r} - \beta\underline{C}^{**}\right] \\
&+ \left[\frac{\rho_2(G_{2,3})\,[1-\rho_3(G_{2,3})]}{1-[1-\rho_2(G_{2,3})]\,[1-\rho_3(G_{2,3})]}\right]\left[\frac{\Pi^1_{FFD}}{r} - \beta\underline{C}^{**}\right] \\
&+ \left[\frac{[1-\rho_2(G_{2,3})]\,\rho_3(G_{2,3})}{1-[1-\rho_2(G_{2,3})]\,[1-\rho_3(G_{2,3})]}\right]\left[(1-\beta)\frac{\Pi^1_{FDF}}{r} + \beta\frac{\Pi^1_{DFF}}{r}\right] - (1-\beta)C^*
\end{aligned}$$

The subgame $G_{1,3}$. Again we previously obtained

$$\rho_1(G_{1,3}) = \frac{\frac{\Pi^3_{DFF}}{r} - \left(\frac{\Pi^3_{FDF}}{r} - C^{**}\right)}{\frac{\Pi^3_{FFF}}{r} - \frac{\Pi^3_{FDF}}{r}}$$

$$\rho_3(G_{1,3}) = \frac{(1-\beta)\left(\frac{\Pi^1_{DFF}}{r} - \frac{\Pi^1_{FFD}}{r} + \underline{C}^{**}\right)}{\frac{\Pi^1_{FFF}}{r} - \frac{\Pi^1_{FFD}}{r}}$$

so

$$\begin{aligned}
V^1(DFD \quad \mid \quad G_{1,2,3}) &= V^1(DFD \mid G_{1,3}) - (1-\beta)C^* \\
= \quad & \left[\frac{\rho_1(G_{1,3})\rho_3(G_{1,3})}{1-[1-\rho_1(G_{1,3})]\,[1-\rho_3(G_{1,3})]}\right]\left[\frac{\Pi^1_{FFF}}{r} - (1-\beta)\underline{C}^{**}\right] \\
&+ \left[\frac{\rho_1(G_{1,3})\,[1-\rho_3(G_{1,3})]}{1-[1-\rho_1(G_{1,3})]\,[1-\rho_3(G_{1,3})]}\right]\left[\frac{\Pi^1_{FFD}}{r} - (1-\beta)\underline{C}^{**}\right] \\
&+ \left[\frac{[1-\rho_1(G_{1,3})]\,\rho_3(G_{1,3})}{1-[1-\rho_1(G_{1,3})]\,[1-\rho_3(G_{1,3})]}\right]\left[(1-\beta)\frac{\Pi^1_{DFF}}{r} + \beta\frac{\Pi^1_{FDF}}{r}\right]
\end{aligned}$$

The subgame G_{12} As before we have

$$\rho_1(G_{1,2}) = \rho_2(G_{1,2}) \equiv \rho_{12}(G_{1,2}) = \frac{(1-2\beta)\left(\frac{\Pi^1_{DFF}}{r} - \frac{\Pi^1_{FDF}}{r} + C^{**}\right)}{\frac{\Pi^1_{FFF}}{r} - (1-\beta)\frac{\Pi^1_{FDF}}{r} - \beta\frac{\Pi^1_{DFF}}{r} - \beta C^{**}}$$

so

$$V^1(DDF \mid G_{1,2,3}) = V^1(DDF \mid G_{1,2}) = \left(\frac{\rho_{12}(G_{1,2})}{2-\rho_{12}(G_{1,2})}\right) V^1(FFF \mid G_{1,2})$$

$$+\left(\frac{1-\rho_{12}(G_{1,2})}{2-\rho_{12}(G_{1,2})}\right) V^1(FDF \mid G_{1,2}) + \left(\frac{1-\rho_{12}(G_{1,2})}{2-\rho_{12}(G_{1,2})}\right) V^1(DFF \mid G_{1,2})$$

$$= \left(\frac{\rho_{12}(G_{1,2})}{2-\rho_{12}(G_{1,2})}\right)\left(\frac{\Pi^1_{FFF}}{r} - C^{**}\right) + \left(\frac{1-\rho_{12}(G_{1,2})}{2-\rho_{12}(G_{1,2})}\right)\left[(1-\beta)\left(\frac{\Pi^1_{FDF}}{r} - C^{**}\right) + \beta\frac{\Pi^1_{DFF}}{r}\right]$$

$$+\left(\frac{1-\rho_{12}(G_{1,2})}{2-\rho_{12}(G_{1,2})}\right)\left[(1-\beta)\frac{\Pi^1_{DFF}}{r} + \beta\left(\frac{\Pi^1_{FDF}}{r} - C^{**}\right)\right]$$

this supplies all the terms necessary to compute and simulate $\rho_3(G_{1,2,3})$.

4.4 Appendix 4 - Proof that Information Sharing is an Individually Rational Strategy for *keiretsu* Firms.

We shall demonstrate this result for the subgame $G_{2,3}$ the proof for the subgame $G_{1,3}$ differs only in notation and is omitted. We need to show that .$\frac{\partial V^1(FDD|G_{2,3})}{\partial \underline{C}^{**}} < 0$. Following the methods used above the value function $V^1(FDD \mid G_{2,3})$ may be constructed as

$$V^1(FDD \mid G_{2,3}) = \rho_2(G_{2,3})\rho_3(G_{2,3})\left[(1-\beta)\,\Pi^1_{FFF} + \beta\Pi^2_{FFF} - \beta\underline{C}^{**}\right]$$

$$+\rho_2(G_{2,3})(1-\rho_3(G_{2,3}))\left[(1-\beta)\,\Pi^1_{FFD} + \beta\Pi^2_{FDF} - \beta\underline{C}^{**}\right]$$

$$+(1-\rho_2(G_{2,3}))\rho_3(G_{2,3})\left[(1-\beta)\,\Pi^1_{FDF} + \beta\Pi^2_{DFF}\right]$$

$$+(1-\rho_2(G_{2,3}))(1-\rho_3(G_{2,3}))V^1(FDD \mid G_{2,3})$$

Rearranging and exploiting the symmetry between the two group firms allows us to simplify this to

$$V^1(FDD \mid G_{2,3}) = \left[\frac{\rho_2(G_{2,3})\rho_3(G_{2,3})}{(1-\rho_2(G_{2,3}))(1-\rho_3(G_{2,3}))}\right]\left[\Pi^1_{FFF} - \beta\underline{C}^{**}\right]$$
$$+\left[\frac{\rho_2(G_{2,3})}{(1-\rho_2(G_{2,3}))}\right]\left[\Pi^1_{FFD} - \beta\underline{C}^{**}\right] + \left[\frac{\rho_3(G_{2,3})}{(1-\rho_3(G_{2,3}))}\right]\left[(1-\beta)\,\Pi^1_{FDF} + \beta\Pi^1_{DFF}\right].$$

Now the entry probabilities are as in appendix 3

$$\begin{aligned}
\rho_2(G_{2,3}) &= \frac{\frac{\Pi^1_{DFF}}{r} - \frac{\Pi^1_{FDF}}{r} + C^{**}}{\frac{\Pi^1_{FFF}}{r} - \frac{\Pi^1_{FDF}}{r}}, \\
\rho_3(G_{2,3}) &= \frac{(1-\beta)\left(\frac{\Pi^1_{DFF}}{r} - \frac{\Pi^1_{FFD}}{r} + \underline{C}^{**}\right)}{\frac{\Pi^1_{FFF}}{r} - \frac{\Pi^1_{FFD}}{r}}.
\end{aligned}$$

Differentiating $\rho_3(G_{2,3})$ with respect to $\underline{C}^{**}$ gives,

$$\frac{\partial\rho_3(G_{2,3})}{\partial\underline{C}^{**}} = \frac{(1-\beta)}{\frac{\Pi^1_{FFF}}{r} - \frac{\Pi^1_{FFD}}{r}} < 0.$$

Differentiating $V^1(FDD \mid G_{2,3})$ with respect to $\underline{C}^{**}$ simplifying a little and using $\frac{\partial\rho_3(G_{2,3})}{\partial\underline{C}^{**}} < 0$ gives,

$$\frac{\partial V^1(FDD \mid G_{2,3})}{\partial\underline{C}^{**}} = \left[\frac{\rho_2(G_{2,3})}{(1-\rho_2(G_{2,3}))^2}\right]\left[\Pi^1_{FFF} - \beta\underline{C}^{**}\right]\left[\frac{\partial\rho_3(G_{2,3})}{\partial\underline{C}^{**}}\right]$$
$$+\left[\frac{1}{(1-\rho_2(G_{2,3}))}\right]\left[(1-\beta)\,\Pi^1_{FDF} + \beta\Pi^1_{DFF}\right]\left[\frac{\partial\rho_3(G_{2,3})}{\partial\underline{C}^{**}}\right] - \beta\left[\frac{\rho_2(G_{2,3})}{(1-\rho_3(G_{2,3}))}\right] < 0.$$

Hence sharing information is individually rational for a *keiretsu* firm.

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