Endogenous Market Structure with Discrete Product Differentiation and Multiple Equilibria: An Empirical Analysis of Competition Between Banks and Thrifts*

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Abstract

We consider a simple model of market structure determination with discrete product differentiation and strategic interaction between firms. Our equilibrium concept is based on a set of relatively weak conditions that describe the profits of active and potential firms in a market. In our model, an observed market structure is an equilibrium if all firms in the market are profitable and no other firms could profitably enter. Given the weak nature of our equilibrium concept, our model admits multiple equilibria. Rather than imposing additional restrictions on the nature of the entry process or the profit functions of firms to circumvent the multiplicity problems, we employ an estimation approach that explictly incorporates the multiple equilibria. We implement this approach to study the determinants of market structure patterns for banks and thrifts in localized banking markets.

A fundamental issue in economics is the relationship between market structure and market outcomes. As a market moves from monopoly to perfect competition, theory generally predicts that prices and mark-ups will fall, output will rise and overall social welfare will increase. However, any study purporting to show an empirical relationship between market structure and some market outcome must confront the fact that the former is inherently

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endogenous. The structure of a market will be determined by numerous factors such as the nature of competition between firms and market demand and cost conditions. If firms can easily enter a market, the threat of entry may be sufficient to discipline incumbent firms. Conversely when entry is difficult, incumbent firms may not be disciplined by the threat of actual or potential competitors. Moreover, firms may have other means at their disposal, such as the ability to differentiate, that mute the competitive effects of entry.

Beginning with Bresnahan and Reiss (1990) and Berry (1992), researchers have developed empirical approaches that explicitly model the determinants of market structure in order to examine the forces that drive market structures in oligopolistic industries.[1] Most importantly, these models recognize the impact that strategic interaction between potential firms has on the resulting market structure. Since the decision of each firm about whether to operate in a market depends on the entry decisions of all other potential firms, this analysis appropriately views the market structure as the result of a game between firms. In the empirical analysis, observed market configurations are then related to the model through conditions that are explicitly derived from a characterization of the equilibrium of the game.

A particularly important line of current research attempts to empirically analyze the determinants of product differentiation in oligopolistic markets. Given recent developments in methods to examine competition in markets characterized by product differentiation (Berry, Levinsohn and Pakes 1995), analysis of the processes that determine the extent of differentiation is an important extension. Notwithstanding difficulties of existence and multiplicity of equilibria in models of endogenous product differentiation where the strategy space is large, significant progress has been made on this front (e.g. Seim 2002).

In a recent paper, Mazzeo (2002) develops and estimates a model of endogenous product differentiation. In his framework, potential firms choose from a set of discrete alternatives including various product types and the option of not entering. As in other models of discrete games, Mazzeo's general framework admits multiple equilibria even when the number of product types is small. To circumvent these multiplicity problems, Mazzeo imposes various restrictions on the latent payoff functions and the form of the entry game. These assumptions effectively serve as a selection mechanism in regions of multiplicity by placing additional restrictions on the profits associated with different equilibrium configurations. Using these assumptions, Mazzeo employs data on hotels in a cross-section of markets to examine the relationship between product differentiation, market characteristics and resulting market

[1] See, for example, Reiss and Spiller (1989), Berry and Waldfogel (1999), Toivanen and Waterson (2001), and Manuszak (2002).

structures.

Tamer (2003) proposes an alternative approach to deal with multiple equilibria in discrete games. Rather than imposing additional structure on the entry process to insure uniqueness as in Mazzeo (2002) or focusing on outcome features that are common across equilibria as in Bresnahan and Reiss (1990) or Berry (1992), Tamer presents a technique that explicitly incorporates multiple equilibria. The basic idea is as follows. Models with multiple equilibria do not provide exact probabilities for possible outcomes as would be required in maximum likelihood. More concretely, certain values of the unobservables in the model cannot be uniquely assigned to particular equilibria. However, it may be possible to obtain *bounds* on the probabilities associated with different outcomes. An upper bound for a specific outcome would result if that outcome always occurred in the region of multiplicity while a lower bound would result if the outcome never occurred in that region. As we will subsequently discuss, Tamer shows that these bounds may permit estimation of the parameters of the payoff functions.

In this paper, we adapt Tamer's approach to analyze entry games with discrete product differentiation. As in Mazzeo's model, firms can choose different discrete product types or can choose not to enter the market. We base our equilibrium concept on a relatively weak set of conditions that payoffs must satisfy to yield a particular configuration of firms. Specifically, we consider an outcome to be an equilibrium if all firms of each product type in the market are profitable and no additional firms of any type wish to enter. We view these requirements as a set of minimal steady state conditions that would be expected to hold for any resulting market structure regardless of the actual entry process. Moreover, these conditions are necessary for an outcome to be a Nash equilibrium of a wide variety of possible entry games.

As is standard in strategic entry models and is especially true given our relatively weak equilibrium conditions, our model yields multiple equilibria. That is, for given payoff functions involving particular values of the unobservables, multiple industry configurations may satisfy our equilibrium conditions. However, we do not wish to impose additional structure on the entry process as in Mazzeo (2002), nor do we wish to focus on outcome characteristics that are common across equilibria as in Bresnahan and Reiss (1990) or Berry (1992). The former may yield results that are sensitive to the assumed structure of the game while the latter may involve ignoring information of specific interest. Moreover, both of these approaches involve restrictions on payoffs which may be testable rather than necessary. Our adaptation of Tamer's approach avoids these potential problems.

We implement our empirical model using data on configurations of banks and thrifts in a cross-section of regional markets. Using data from a variety of sources, we examine the factors that influence the number of banks and thrifts in a market. The estimates provide indirect information about the extent of competition between banks and thrifts via the effect that the presence of one type of firm in a market has on the attractiveness of that market for firms of the opposite type. The degree of competition between banks and thrifts is of particular interest due to concerns about defining the appropriate product market for regulatory purposes such as merger evaluation. We estimate a variety of models including our general model and a model in which we alter our equilibrium conditions to reflect Mazzeo's assumption of sequential entry.

Our approach parallels the analysis of Ciliberto and Tamer (2003). In their study of entry by airlines into city-pair markets, they employ weak conditions on profitability required to yield a particular market configuration that are similar to our equilibrium conditions. As in our model, their set-up yields multiple equilibria. Moreover, many of the issues that arise in our application regarding the ability to characterize general features of the equilibria, such as the number of firms, also occur in their analysis.

The paper is structured as follows. The following section describes our basic framework, illustrates the multiplicity problem and discusses some assumptions that could alleviate that problem. Next, we discuss our estimation strategy. The third section provides a general discussion of banks and thrifts and describes the data on regional market structures for banks and thrifts that we employ in our empirical analysis. The subsequent section presents the estimation results while the final section concludes.

A Simple Model of Endogenous Product Differentiation

We consider a situation in which two types of firms $t \in \{1, 2\}$ can enter a market.[2] Firms of each type are potentially different from one another, but we do not explicitly model the nature of differentiation (e.g. vertical differentiation). Firms in a market compete with one another and make entry and exit decisions. We do not directly observe the outcome of competition in a market, nor do we observe any industry dynamics. Instead, for each market,

[2] While we only allow for two firm types in the current paper, our approach could be extended to additional types. For expositional purposes and since our empirical application will involve two types, we focus on this simple case. Moreover, with additional types, the extent of multiplicity could become enormous. We speculate that the data requirements would be correspondingly large.

we observe a configuration that we assume is the long-run outcome of the competitive process and associated industry evolution.

We assume that an infinite pool of potential entrants of each type exists in each market and that each firm of a given type is equally profitable following entry.[3] The discounted expected present value of profits for a type t firm in market m is summarized by the following payoff function

$$\pi_t\left(N_1, N_2, X_{tm}, \varepsilon_{tm}; \theta_t\right) = \overline{\pi}_t\left(N_1, N_2, X_{tm}; \theta_t\right) + \varepsilon_{tm} \quad (1)$$

where $\overline{\pi}_t\left(N_1, N_2, X_{tm}; \theta_t\right)$ is a component of profits for a type t firm that is known to the econometrician up to the parameters θ_t, and ε_{tm} is an unobserved component of profits for a firm of type t in market m. In this expression, N_t is the number of type t firms in the market, X_{tm} are characteristics of market m that impact the profitability of a type t firm, and θ_t are parameters of the payoff function for a type t firm. The unobservables for market t, $(\varepsilon_{1m}, \varepsilon_{2m})$, are independent of the market characteristics (X_{1m}, X_{2m}) and have a joint distribution that is known up to some parameters Ω.

We interpret this payoff function as a reduced form profit function representing the outcome of current and expected future product market competition. All market participants including actual and potential firms observe all components of profits. Hereafter, we will suppress the dependence of π_t on all factors except for the number of firms for notational convenience.

While we do not directly observe profits, we do observe the number of firms of each type as well as market characteristics for a sample of independent markets. The empirical exercise involves drawing inferences about underlying latent profitability using restrictions required for the observed outcomes to be an equilibrium. These equilibrium conditions generally place inequality restrictions on the latent payoff functions that must be satisfied for a particular configuration to obtain. The stochastic specification of profits translates these conditions into restrictions on the unobservable components of payoffs. Given the distribution of these unobservables, we can in principle compute the probabilities associated with different market structures. Although we will not actually use maximum likelihood to estimate our model except in special cases, we could then consider estimating the parameters (θ_1, θ_2) as well as any parameters characterizing the distribution of the unobservables by, for

[3] Admittedly, this assumption places strong restrictions on heterogeneity across firms within a given type. However, without at least some information about actual and potential firms as in Berry (1992) or Ciliberto and Tamer (2003), it is difficult to implement an empirical model that contains observed or unobserved heterogeneity across firms.

example, selecting parameters that maximize the likelihood of our observed data.[4] However, in our general model, the equilibrium conditions will not yield exact probabilities for different market structures, thereby precluding application of maximum likelihood.

We consider a relatively weak set of equilibrium conditions. In particular, we do not wish to place any restrictions on the way in which the entry process has taken place. As a result, we define the outcome (N_1^*, N_2^*) to be an equilibrium configuration if the following four conditions hold:

$$\pi_1 (N_1^*, N_2^*) > 0 \tag{C1}$$

$$\pi_2 (N_1^*, N_2^*) > 0 \tag{C2}$$

$$\pi_1 (N_1^* + 1, N_2^*) < 0 \tag{C3}$$

$$\pi_2 (N_1^*, N_2^* + 1) < 0. \tag{C4}$$

In other words, a configuration is an equilibrium if all firms of each type that operate in the market are profitable and no additional firms of either type could profitably enter.

We view these conditions as a reasonable, but minimal, set of conditions that would need to be satisfied for a market structure to be an equilibrium regardless of the actual entry process. At the very least, we would want an equilibrium to reflect that all firms observed in a market expect to be profitable from being in that market while the failure to observe additional firms reflects their beliefs about the lack of profit opportunities. Moreover, our equilibrium conditions are necessary conditions for an outcome to be an equilibrium in a wide variety of more formal models about the entry process. For instance, C1 through C4 will be necessary conditions for a configuration to be a (pure strategy) Nash equilibrium of a simultaneous move entry game. As we discuss below, these conditions are necessary, but not sufficient, for a configuration to be a subgame perfect equilibrium of the sequential move entry game employed by Mazzeo (2002).[5] Refinements of our equilibrium concept based on

[4] Intuitively, this type of approach extends analysis of discrete single-agent decision processes in which observed choices are used to infer features of underlying latent utilities. The crucial difference between this setting and the single-agent problem lies in the interaction of the agents' decisions. This feature of the model gives rise to an econometric framework involving endogenous dummy variables (see Bresnahan and Reiss 1991).

[5] Interestingly, conditions C1 - C4 do not necessarily hold in the Nash equilibrium of the alternative game considered by Mazzeo (2002) in which firms enter in a first stage and then choose their product types in a second stage. Intuitively, this two stage game prevents additional entry in the second stage even if such entry appears profitable ex post due to the restricted number of entrants from the first stage. However, a repeated version of this game would require something analogous to our equilibrium conditions. This observation along with other examples such as a one-shot simultaneous move entry game involving a mixed strategy equilibrium lead us to use somewhat more agnostic terms when referring to the equilibrium conditions.

specific entry games would place additional restrictions on profits. While such restrictions may facilitate our ability to estimate features of underlying profitability, the associated cost is the possibility that the additional restrictions yield a misspecified model. We wish to avoid such potential problems and, hence, focus on a less stringent set of equilibrium conditions.

To guarantee the existence of an equilibrium configuration, we assume that profits of each type are strictly decreasing in the number of firms of either type so that

$$\pi_t(N_1, N_2) > \pi_t(N_1 + 1, N_2) \tag{A1}$$

$$\pi_t(N_1, N_2) > \pi_t(N_1, N_2 + 1) \tag{A2}$$

for each product type t.[6] With these restrictions on profits, one can easily establish that at least one equilibrium configuration always exists. In terms of the stochastic structure of our model, for any market characteristics $X_m = (X_{1m}, X_{2m})$ and parameters (θ_1, θ_2) such that these assumptions hold, at least one configuration that satisfies C1 - C4 always exists for every possible value of ε_{1m} and ε_{2m}.

Given the weak nature of our equilibrium concept, it is not surprising that this framework admits multiple equilibria. In fact, multiple equilibria will *always* exist when considering configurations that involve a non-zero number of firms of either type. In other words, given any configuration with a non-zero number of firms of either type, certain payoff values that satisfy C1 -C4 for that configuration will also satisfy those conditions for other market structures. For instance, consider the following values of the profit functions: $\varepsilon_1 > -\overline{\pi}_1(1,0)$, $\varepsilon_1 < \min\{-\overline{\pi}_1(1,1), -\overline{\pi}_1(2,0)\}$, $\varepsilon_2 > -\overline{\pi}_2(0,1)$, $\varepsilon_2 < \min\{-\overline{\pi}_2(1,1), -\overline{\pi}_2(0,2)\}$.[7] Since $\varepsilon_1 > -\overline{\pi}_1(1,0)$, a single type 1 firm would wish to enter facing an unoccupied market. Moreover, an additional type 1 firm would not enter since $\varepsilon_1 < -\overline{\pi}_1(2,0)$, nor would a type 2 firm enter given an incumbent type 1 firm since $\varepsilon_2 < -\overline{\pi}_2(1,1)$. Thus, payoffs that satisfy these restrictions would yield (1,0) as an equilibrium configuration. However by similar logic, (0,1) would be an equilibrium configuration. Given the assumption that profits strictly decrease in the number of firms of either type, regions of $(\varepsilon_1, \varepsilon_2)$ that satisfy these conditions *always* exist thereby yielding multiple equilibrium configurations.

Intuitively, conditions C1 - C4 define rectangles that involve restrictions on the unobserved components of the profit functions required for a particular outcome to be an equilibrium. Multiple equilibria arise when these rectangles overlap, that is, when the equilibrium

[6] In fact, all that we really require is that profits strictly decrease in the number of own-type firms and weakly decrease in the number of other-type firms.

[7] The "min" operator arises because we do not wish (at this point) to place restrictions on the ordering of, for example, $\overline{\pi}_1(1,1)$ and $\overline{\pi}_1(2,0)$.

conditions are simultaneously satisfied for two or more configurations. These overlapping regions always exist for our equilibrium concept. Figures 1 through 3 illustrate some examples of multiplicity in our framework where we have restricted attention to at most two entrants of each type for tractability. These figures, which depict $(\varepsilon_1, \varepsilon_2)$ space, differ in the ordering of payoffs across different market structures. In figure 2, more than two outcomes are equilibria for certain $(\varepsilon_1, \varepsilon_2)$ values as seen in the region where (1,1), (2,0) and (0,2) are all equilibria. Figure 3 depicts a situation in which neither the total number of firms nor the types is unique as both (2,0) and (0,1) can be equilibria for certain values of the unobservables.

This multiplicity problem is directly analogous to the problem discussed by Bresnahan and Reiss (1990) and Berry (1992) in the context of entry into homogeneous goods markets. In their models, multiplicity arises regarding the identity of the entrant. In the current framework where we have assumed away issues related to the identity of entrants except for their type, multiplicity arises in terms of the types of entrants and number of each type.

Multiple equilibria are endemic to models of discrete decisions with strategic interaction (Bresnahan and Reiss 1991). Moreover, multiplicity generally complicates empirical analysis of such models. For instance, direct application of maximum likelihood for such a model would be infeasible since the model does not yield exact probability statements for each outcome. The standard approaches to deal with multiplicity are to place restrictions on the payoff functions, make assumptions about the nature of the game, or focus on some aspect of the outcome that is unique across equilibria.[8] The following discussion will address the implications of these approaches for our framework.

One convenient and potentially reasonable restriction on the payoff functions would be that profits for a particular type decline more with entry of another firm of the same type than with entry of a different type of firm holding all other factors, such as market characteristics, constant. Formally, these assumptions would imply

$$\pi_1 (N_1 + 1, N_2) < \pi_1 (N_1, N_2 + 1) \qquad \text{(A3)}$$

$$\pi_2 (N_1, N_2 + 1) < \pi_2 (N_1 + 1, N_2) . \qquad \text{(A4)}$$

The primary implication of these assumptions would be that the aggregate number of firms is unique across equilibria.[9] Intuitively, when we take an equilibrium with some total number

[8] Alternatively, one could impose Heckman's (1978) "coherency" condition which would yield a recursive model, but would effectively remove the strategic interaction. One could also employ the ad hoc equilibrium selection approach of Bjorn and Vuong (1984) in regions of multiplicity.

[9] To verify uniqueness, note that if (N_1^*, N_2^*) satisfies C1 - C4, then trivially neither $(\widetilde{N}_1, \widetilde{N}_2) \geq (N_1^*, N_2^*)$

of firms and alter that configuration in a way that yields more or fewer total firms, the asymmetry of competitive effects across types will create either a situation in which a particular type will wish to enter (if we remove too many firms of its type) or a situation in which a particular type will be unprofitable (if we add too many firms of its type). In terms of the earlier figures depicting regions of multiplicity, this assumption would rule out the situation in figure 3.

Uniqueness in the total number of firms could be exploited for estimation purposes. Following Bresnahan and Reiss (1990) and Berry (1992), we could perform maximum likelihood estimation based on the aggregate number of firms. However, such an approach would obscure information about the crucial issues of interest in a study of endogenous product differentiation, namely the way in which competitive effects differ depending on a firm's type and the types of competing firms. Moreover, assumptions A3 - A4 and the associated uniqueness result will not be necessary in the estimation approach that we employ. While it would simplify the estimation, we generally prefer not to impose such an assumption if it is not necessary.

Mazzeo (2002) considers modelling the entry process as a sequential move game in which potential firms sequentially make irrevocable decisions about entry and product type. This sequential move assumption yields additional conditions that must be satisfied in a subgame perfect equilibrium. Specifically, in addition to the necessary conditions C1 - C4, the following conditions must hold:

$$\pi_1\left(N_1^*, N_2^*\right) > \pi_2\left(N_1^*-1, N_2^*+1\right) \tag{C5}$$

$$\pi_2\left(N_1^*, N_2^*\right) > \pi_1\left(N_1^*+1, N_2^*-1\right). \tag{C6}$$

These conditions require that the last entrant into the market did not wish to change her type.[10]

nor $(\widetilde{N}_1, \widetilde{N}_2) \leq (N_1^*, N_2^*)$ can satisfy the equilibrium conditions. Next, $\widetilde{N}_1 > N_1^*$, $\widetilde{N}_2 < N_2^*$ with $\widetilde{N}_1 + \widetilde{N}_2 < N_1^* + N_2^*$ cannot be an equilibrium since $0 < \pi_2\left(N_1^*, N_2^*\right) < \pi_2\left(N_1^*+1, N_2^*-1\right) < ... < \pi_2(\widetilde{N}_1, N_2^* - (\widetilde{N}_1 - N_1^*)) \leq \pi_2(\widetilde{N}_1, \widetilde{N}_2+1)$ so that a type 2 firm would want to enter in configuration $(\widetilde{N}_1, \widetilde{N}_2)$ where the first inequality follows from the definition of (N_1^*, N_2^*), subsequent strict inequalities follow from A4, and the last weak inequality follows from A2 and the assumption that $\widetilde{N}_2 < N_2^* - (\widetilde{N}_1 - N_1^*)$. Exploiting A3 in a similar way when $\widetilde{N}_1 > N_1^*$, $\widetilde{N}_2 < N_2^*$ with $\widetilde{N}_1 + \widetilde{N}_2 > N_1^* + N_2^*$, the equilibrium condition would be violated for type 1 firms since profits would be negative under $(\widetilde{N}_1, \widetilde{N}_2)$. Symmetric results apply to the cases where $\widetilde{N}_1 < N_1^*$, $\widetilde{N}_2 > N_2^*$.

[10] More precisely, the last entrant of a particular must prefer her payoff to what she would receive were she to change her type. The difference between this statement and C5 - C6 is that (N_1^*-1, N_2^*+1) on the right hand side of C5, for example, need not be the outcome that would obtain off the equilibrium path were the last type 1 to change to 2. However, under A1 - A4, the total number of firms would remain the same.

The key implication of the sequential move assumption is that, given A1 - A4, C1 - C6 uniquely determine equilibrium configurations for any value of the payoff functions.[11] That is, given any X_m, θ_1 and θ_2 such that the assumptions A1 - A4 are satisfied, exactly one equilibrium configuration is consistent with each value of $(\varepsilon_1, \varepsilon_2)$. This is an important observation by Mazzeo since it allows us to compute exact probabilities associated with each possible market structure in order to directly employ maximum likelihood estimation.

In our framework, the sequential move assumption serves as an equilibrium selection mechanism. Conditions C5 - C6 partition the regions of multiplicity and uniquely allocate parts of those regions to particular outcomes. Figures 1 and 2 illustrate these partitions.[12] Consider the earlier case where (1,0) or (0,1) were equilibrium configurations given our definition. For (1,0) to be an equilibrium of the sequential move game, we require $\pi_1(1,0) > \pi_2(0,1)$. However, exactly the opposite condition must hold for (0,1) to be an equilibrium of the sequential move game. Hence, for any $(\varepsilon_1, \varepsilon_2)$ such that our basic equilibrium conditions are satisfied for both (1,0) and (0,1), $(\varepsilon_1, \varepsilon_2)$ trivially cannot satisfy both $\pi_1(1,0) > \pi_2(0,1)$ and $\pi_2(0,1) > \pi_1(1,0)$. The sequential move assumption allocates the region of multiplicity to exactly one of the possible outcomes that satisfies the basic equilibrium conditions.

Mazzeo's assumption is attractive because it permits us to use a standard maximum likelihood approach to estimate features of the payoff functions. Moreover, uniqueness is obtained via additional constraints on the payoffs that are derived from the equilibrium of a formal entry game. In our empirical analysis, we will estimate a version of the model in which we use this refinement of our basic equilibrium concept. Since the sequential move model involves somewhat irregular regions of integration to form the outcome probabilities, we will employ simulation methods as suggested by Berry (1992). However, in the subsequent section, we will present an alternative approach to deal with the multiple equilibria in the model.

Estimation with Multiple Equilibria

The previous section illustrated the extent of multiple equilibria that can arise in a

[11] To verify this claim, note that for any candidate equilibrium configuration (N_1^*, N_2^*), assumptions A1 - A4 imply that we need only consider alternative equilibria with the same aggregate number of firms. For any values of $(\varepsilon_1, \varepsilon_2)$ that satisfy C1 - C4 for multiple configurations and also satisfy conditions C5 and C6 for (N_1^*, N_2^*), one firm exchanges will be ruled out by the new conditions C5 and C6. That is, one of the new conditions will rule out $(N_1^* + 1, N_2^* - 1)$ while the other will rule out $(N_1^* - 1, N_2^* + 1)$. Conditions A5 and A6 will then imply that two or greater firm exchanges are also ruled out.

[12] Recall that this partition is not relevant for figure 3 since we must maintain assumptions A3 and A4 to obtain uniqueness.

simple model of entry with discrete product differentiation. While various alterations of the base model can alleviate this complication, we are concerned about the possibility that the additional structure imposed on the entry process by Mazzeo (2002) may contaminate the estimation results. Moreover, we wish to place as few restrictions on the profit functions as possible. In this section, we will discuss an alternative estimation approach based only our base equilibrium conditions along with the restriction that profits are non-increasing in the number of competing firms to insure that such an equilibrium exists. This approach, based on Tamer (2003), explicitly incorporates the presence of multiple equilibria without requiring ad hoc or potentially invalid adjustments to our simple model.

The difficulty for maximum likelihood estimation is failure of the equilibrium conditions to yield exact probabilities for the possible market structures. Given a market structure (N_1^*, N_2^*) involving a non-negative number of either type, certain regions of the unobservables could yield that configuration, but could also be consistent with alternative configurations. However, given parameters for the profit function, we can identify the regions of $(\varepsilon_1, \varepsilon_2)$ that are associated exclusively with (N_1^*, N_2^*) as well as those regions that are consistent with both (N_1^*, N_2^*) and other market structures. Hence, we can bound the probability of observing (N_1^*, N_2^*). We can then obtain consistent estimates of the structural parameters of the latent profit functions by using the modified minimum distance estimation approach suggested by Manski and Tamer (2002). This approach involves minimizing the distance between the set of probabilities for (N_1^*, N_2^*) that the model yields and a consistent estimate of the conditional population probabilities of (N_1^*, N_2^*).

More formally, we can obtain the upper bound on the probability of $y = (N_1^*, N_2^*)$ by assuming that the observed outcome always obtains in the region of multiplicity. That is,

$$U_y\left(X;\theta\right) = \Pr\left(C1 - C4 \text{ hold for } y|X;\theta\right). \tag{2}$$

For example, the upper bound for the configuration $(1,0)$ in figure 1 is given by

$$U_{(1,0)}\left(X;\theta\right) = \int_{-\infty}^{-\overline{\pi}_2[(1,1),X_2;\theta_2]} \int_{-\overline{\pi}_1[(1,0),X_1;\theta_1]}^{-\overline{\pi}_1[(2,0),X_1;\theta_1]} dF\left(\varepsilon_1, \varepsilon_2; \Omega\right). \tag{3}$$

We can then compute the lower bound on the probability of observing y by assuming that the configuration never occurs in the region of multiplicity yielding

$$L_y\left(X;\theta\right) = \Pr\left(C1 - C4 \text{ hold for } y\ \cap C1 - C4 \text{ do not hold for any } y' \neq y|X;\theta\right). \tag{4}$$

Continuing the previous example, this calculation would involve subtracting the probability associated with the rectangle where $(1,0)$ and $(0,1)$ are both equilibria or, in other words,

$$L_{(1,0)}(X;\theta) = U_{(1,0)}(X;\theta) - \int_{-\overline{\pi}_2[(0,1),X_2;\theta_2]}^{-\overline{\pi}_2[(1,1),X_2;\theta_2]} \int_{-\overline{\pi}_1[(1,0),X_1;\theta_1]}^{-\overline{\pi}_1[(1,1),X_1;\theta_1]} dF(\varepsilon_1,\varepsilon_2;\Omega). \tag{5}$$

As this example illustrates, the calculation of both the upper and lower bounds involves combinations of integrals over simple rectangles. However, our hesitancy to impose additional restrictions on the latent profit functions implies that these calculations can become quite involved depending on whether the scenario in figure 1, 2 or 3 results from the parameters of the profit functions. We can compute the upper bound for a market structure using standard numerical techniques. However, calculation of the lower bound is more involved due to the number of potential regions involving multiplicity. To compute the lower bound, we employ simulation techniques by drawing R values for $(\varepsilon_1,\varepsilon_2)$ from the distribution $F(.)$. To increase the relevance of our simulated draws, we transform R draws from a uniform distribution such that the resulting simulated values of $(\varepsilon_1,\varepsilon_2)$ are drawn from the distribution $F(.)$ in the region that is consistent with the market structure y of interest. For these draws, which are by construction consistent with y, we can then obtain the lower bound by computing the frequency of draws that are not consistent with any other market structure.[13]

These bounds yield a set of inequality restrictions that form the basis of our estimator. Combining the two bounds, we have the following inequality restrictions on the conditional probability of market structure y

$$L_y(X;\theta) \leq P(y|X) \leq U_y(X;\theta). \tag{6}$$

If we directly observed the conditional probabilities of the different market structures, $P(y|X)$, we could employ a conditional moment restriction based on (6). We could then choose parameter values that, for a sample of data, "minimizes the distance" (in a sense to be made precise below) between the conditional probabilities and the bounds. However, a complication arises since we do not know the actual population outcome probabilities. As a result, we instead use an estimator of these probabilities, $\widehat{P}(y|X)$, that is consistent as the number of markets $M \to \infty$. In our implementation of the model, we use a multinomial logit model

[13] Specifically, if $[a,b]$ is a region consistent with a particular outcome, we obtain a draw from that region via the transformation $\varepsilon = F^{-1}\{u \cdot [F(b) - F(a)] + F(a)\}$ where u is a $U(0,1)$ draw. Repetition of this procedure for R uniform draws generates unobservables from the distribution $F(.)$ in the region $[a,b]$. We then find the fraction of these unobservables that are consistent with at least one other equilibrium. We reweight this fraction by $F(b) - F(a)$ to find the correct simulated probability of that ε will be within $[a,b]$ and will also be consistent with another equilibrium.

estimator to obtain estimates of these conditional probabilities.[14] We can then employ the modified minimum distance estimator of Manski and Tamer (2002) to obtain estimates of the parameters θ by minimizing the distance between the estimated probabilities $\widehat{P}(y|X)$ and the bounds. More specifically, the minimum distance estimator $\widehat{\theta}$ is defined by[15]

$$\widehat{\theta} = \arg\min_{\theta} Q(\theta) = \sum_{m=1}^{M} d\left\{[L_{y_m}(X_m;\theta), U_{y_m}(X_m;\theta)], \widehat{P}(y_m|X_m)\right\} \tag{7}$$

where the distance metric $d(.,.)$ is

$$\begin{aligned} d\left\{[L_y(X;\theta), U_y(X;\theta)], \widehat{P}(y|X)\right\} &= 0 \text{ if } L_y(X;\theta) \leq \widehat{P}(y|X) \leq U_y(X;\theta) \\ &= \left[L_y(X;\theta) - \widehat{P}(y|X)\right]^2 \text{ if } \widehat{P}(y|X) < L_y(X;\theta) \\ &= \left[U_y(X;\theta) - \widehat{P}(y|X)\right]^2 \text{ if } \widehat{P}(y|X) > U_y(X;\theta) \end{aligned} \tag{8}$$

In other words, we attempt to minimize the sum of squared differences over our sample markets between the estimated conditional probabilities and the bounds from the model. This distance is zero when the estimated probability lies within the bounds and the minimum squared difference between the probability and the bounds otherwise.

In our estimation, we actually consider a few variants of this base objective function. Specifically, the general objective function that we consider is

$$Q(\theta) = \sum_{m=1}^{M} \sum_{y=1}^{J} w_m(y)\, d\left\{[L_y(X_m;\theta), U_y(X_m;\theta)], \widehat{P}(y|X_m)\right\} \tag{9}$$

where J is the total number of outcomes y that can occur and $w_m(y)$ is a weight on outcome y for observation m. The three weights that we examine are:

$$w_m(y) = 1 \text{ for all } y \tag{10}$$

$$w_m(y) = 1(y = y_m) \tag{11}$$

$$w_m(y) = \widehat{P}(y|X_m). \tag{12}$$

The first weight implies that all possible outcomes are used when computing the contribution of observation m to the objective function.[16] The second weight involves only the observed

[14] Our use of a logit estimator for these conditional probabilities is similar to the application in Heckman et. al (1998.) We initially attempted to use a multivariate kernel estimator to obtain first stage estimates of $\widehat{P}(y|X)$, but found the estimation to be very problematic due to our relatively small sample size and large number of explanatory variables and outcomes.

[15] This objective function could be viewed as the result of a moment restriction based on (6) in which we must also estimate the nuisance parameter $P(y|X)$.

[16] Having estimated $\widehat{P}(y|X)$, we can compute the probability of any outcome y given an observed value of X_m. We can thus evaluate the model's ability to bound the probabilities for outcomes not observed for observation m.

outcome for observation m when computing its contribution to the objective function. The last involves weighting the outcomes by their empirical probabilities. Implicitly, any minimum distance estimator such as the one presented in (7) involves a weighting matrix on the terms that contribute to the objective function. If the asymptotic variance of the estimator could be derived, one could determine the optimal weighting matrix that yielded the most efficient estimator. As we discuss below, we have not derived the asymptotic variance, partly due to identification concerns. Consequently, we consider these three weighting schemes as an ad hoc approach to analyze the sensitivity of the results to different specifications of the objective function.

An important distinction is the difference between the conditional outcome probabilities and the bounds. In principle, we can nonparametrically obtain consistent estimates of the conditional probabilities $P(y|X)$. While this information provides a description of the way in which the market structures vary with the market characteristics, it does not directly yield information about the "structural" parameters θ that are the real issue of interest. Most notably, knowledge of $P(y|X)$ does not directly provide values of the parameters that describe the competitive effects across firms. The underlying economic model and equilibrium concept then link the conditional probabilities to the parameters of the model. In a standard application without multiple equilibria, this relationship is direct. In other words, the conditional outcome probabilities exactly equal the probabilities yielded by the structural model. In such a situation, a minimum distance approach analogous to the one described above would be possible, although for purposes of efficiency, the standard practice would be to employ maximum likelihood estimation. In our application, the presence of multiple equilibria implies that an one-to-one relationship between the conditional outcome probabilities and the predictions of the model does not exist. Nevertheless, the important insight from Tamer (2003) is that we still have a relationship between the conditional probabilities and the predictions of the model, namely the bounds. Estimation of the parameters of the entry model then requires an approach that links the conditional probabilities to the information that the model provides through the bounds. The minimum distance approach of Manski and Tamer (2002) provides one approach to draw this link.

A crucial issue concerns identification of the parameters θ. However, before discussing identification in more detail, it is useful to present the functional form that we will employ for payoffs as well as some features of our data. Ideally, we would derive our payoff functions, including the additive structure for the unobservable, from primitives in the market such as demand and costs. The equilibrium outcome of competition between firms given these primitives would then yield payoff functions for the firms. The parameters of these payoff functions would involve amalgamations of "deep" parameters reflecting demand and cost conditions. While such an exercise is conceptually appealing, the wide variety of models of firm competition along with the potentially complex nature of demand and costs makes it difficult to implement such an approach. As a result, following Mazzeo (2002) and Seim (2002), we use a more ad hoc specification for the payoff functions. Specifically, we assume that payoffs for a type t firm in market m are given by

$$\pi_t \left(N_1, N_2, X_{tm}, \varepsilon_{tm}; \theta_t\right) = \beta_{t0} + X_m \beta_t + Z_{tm} \gamma_t + \Delta_{t1} N_1 + \Delta_{t2} N_2 + \varepsilon_{tm} \tag{13}$$

where, in an abuse of notation, X_m are characteristics of market m that impact the profitability of all firms while Z_{tm} are characteristics of market m that only impact the profitability of type t firms. As we will subsequently discuss while describing the data, Z_{tm} are binary variables that reflect market-specific regulations applicable to particular types of firms. Exclusion of these variables from the payoffs of the other type of firm involves the implicit assumption that these regulations only impact the fixed cost of entry. While this functional form involves a number of restrictive assumptions, most notably the linear effect of additional firms, it provides a useful starting point. The resulting parameters of interest are: $(\beta_{10}, \beta_1, \beta_{20}, \beta_2)$ which reflect the impact of market characteristics on the two types of firms; (γ_1, γ_2) which capture the impact of type-specific regulations; and $(\Delta_{11}, \Delta_{12}, \Delta_{21}, \Delta_{22})$ which reflect the differential competitive effects across the two types of firms.

One may suspect that the failure of the model to provide exact probabilities for different market outcomes implies that the parameters of the model are not point identified. However, Tamer (2003) demonstrates that the parameters θ may still be identified in the presence of multiple equilibria.[17] Among the factors that facilitate identification are the presence of exclusion restrictions across the payoff functions and the existence of at least some outcomes for which the model does yield exact probabilities. Moreover, even if the model only yields bounds for every outcome, the parameters will still be point identified if the excluded variables exhibit sufficient variation. Specifically, if the excluded variables have full support, then the bounds associated with the true parameters will not intersect with the bounds of other parameters for at least one outcome and value of the explanatory variables.

In principle, we have at least two outcomes for which the model yields exact probabilities,

[17] Conversely, the absence of multiple equilibria is not sufficient for point identification since a model that yields exact probabilities for the outcomes may nevertheless not be identified.

$(0,0)$ and $(N_1^{\max}, N_2^{\max})$ where $N_t^{\max}$ is the maximum number of type t firms that we observe in our data. The $(0,0)$ outcome would obtain when no firm of either type would be profitable even as a monopolist. Similarly, $(N_1^{\max}, N_2^{\max})$ occurs when all $N^{\max}$ firms of each type are profitable in the market using the assumption that no more than $N_t^{\max}$ firms can ever profitably enter. In each of these cases, two of the equilibrium conditions are trivially satisfied so that the outcome occurs when the other two conditions hold. Since we can never observe fewer than 0 firms or more than $N^{\max}$ firms, the probability of these outcomes is then exactly defined by the two relevant equilibrium conditions.

With these two unique outcomes, the model could be re-formulated as a variant of the partially observed bivariate model of Poirier (1980). Specifically, we could consider estimating the parameters using only the unique outcomes with the remainder of the outcomes summarized by a residual probability. Poirier (1980) argues that sufficient conditions for point identification of the payoff function parameters in a partially observed bivariate model are that the error terms have a joint normal distribution and exclusion restrictions hold across the payoff functions.[18] Conceptually, this interpretation of the model is related to the approach of Berry (1992) and Bresnahan and Reiss (1990).

An interpretation of our model in these terms provides an identification argument for some of the parameters. However, estimation based on the unique outcomes will not yield identification of the crucial parameters in our application, namely the competitive effects of different types of firms. Treating the model as a partially observed model would permit us to estimate (β_1, β_2) and (γ_1, γ_2) along with the correlation between the unobservables, but the various competitive coefficients would be indistinguishable from constants in the payoff functions. Specifically, using the $(0,0)$ outcome, we would only be able to identify $\beta_{10} + \Delta_{11}$ for type 1 firms. Similary, the model would identify $\beta_{10} + \Delta_{11} N_1^{\max} + \Delta_{12} N_2^{\max}$ from the $(N_1^{\max}, N_2^{\max})$ outcome. Analogous results would hold for the parameters of the payoff function for type 2 firms. This identification failure is similar to the problem that would arise from applying the techniques of Berry (1992) or Bresnahan and Reiss (1990) to our setting. Intuitively, these outcomes involve insufficient variation in market structures since intermediate cases between 0 and $N^{\max}$ are not considered. Hence, we are not be able to distinguish the separate competitive effects in these two outcomes from an effect that is

[18] See also Maddala (1983). When the distribution of the unobservables is unknown, Ichimura and Lee (1991) show that a continuous exclusion restriction in each equation provides a sufficient condition for identification. In the presence of unique probabilities for some outcomes, Tamer's (2003) analysis requires a single excluded variable with full support.

common across all firms of a given type.[19]

Identification of the competitive effect parameters $(\Delta_{11}, \Delta_{12}, \Delta_{21}, \Delta_{22})$ requires information from the intermediate outcomes for which the model only provides probability bounds. As noted earlier, the presence of the bounds does not preclude identification since the bounds associated with the true parameter values may not intersect with the bounds from each alternative parameter vector for at least one outcome if the regressors exhibit sufficient variation. However, verification of such a property is difficult without exclusion restrictions that have full support.

In light of the possibility that $(\Delta_{11}, \Delta_{12}, \Delta_{21}, \Delta_{22})$ may not be identified, we employ the approach of Chernozhukov, Hong and Tamer (2003) to obtain confidence regions for the identified set of parameters. If we could verify (or were willing to assume) that all of the parameters were point identified, we could derive the asymptotic variance of the estimator by adapting the results of Andrews (1994) to deal with our non-differentiable objective function along with the presence of the nuisance parameter $\widehat{P}(y|X)$.[20] However, the set estimates of Chernozhukov, Hong and Tamer (2003) will provide consistent standard errors under point identification and will also insure against the possibility that some of the parameters may not be point identified.

Banks and Thrifts

We apply the approach discussed in the previous section to analyze regional market structure patterns for banks and thrifts.[21] Banks and thrifts are financial institutions that provide a wide variety of services to consumers and firms. These services include a variety of borrowing and savings products such as consumer loans, small business loans, checking accounts and savings accounts. In 2002, there were approximately 7,900 commercial banks and 1,450 thrifts in the United States. Since the early 1990s, the aggregate number of commercial banks has declined by approximately 3,000 firms while the number of thrifts has declined by 800. In both cases, the declines primarily reflect substantial merger activity, although entry has dampened the consolidation to some extent. Currently, commercial banks

[19] Interestingly, although we cannot point identify the parameters $(\Delta_{11}, \Delta_{12}, \Delta_{21}, \Delta_{22})$ off the unique outcomes, we can characterize the nature of the underidentification. Whether this specific characterization along with additional information from intermediate outcomes might be sufficient for point identification is a topic that we leave to future research.

[20] This analysis might be useful in order to suggest which particular weighting matrix would be optimal in construction of the objective function.

[21] Thrifts include financial institutions such as savings banks and savings and loans.

have total assets of approximately $7.2 trillion while assets of thrifts are approximately 20% of that amount.[22]

Due to different regulatory treatment, banks and thrifts historically did not offer the same types of products. Thrifts were established to provide real estate loans, primarily residential mortgages, that were financed by time deposits. Until the early 1980s, regulatory restrictions precluded thrifts from offering demand deposits. Relaxation of statutory restrictions has allowed thrifts to offer demand deposits as well as to engage in limited commercial and industrial (C&I) lending, although they must hold at least 65% of their assets in Qualified Thrift investments. Conversely, banks have faced less stringent restrictions on the services that they offer.

These historical differences between the two types of institutions led antitrust authorities to effectively treat banks and thrifts as separate markets for the purposes of evaluating proposed bank mergers. Merger evaluation largely involved examining regional markets with the relevant product market involving a "cluster" of bank services, defined as a grouping of several different financial services.[23] Traditionally, antitrust authorities computed Herfindahl-Hirschman Indices (HHIs) using deposit accounts as a proxy for the degree of concentration over the entire cluster of services offered by banks to screen mergers for competitive issues that would require further review. Calculation of the HHIs when evaluating commercial bank mergers did not include thrifts following the Supreme Court ruling in 1974 that thrifts competed in a different product market than banks because they did not offer the same cluster of services.[24]

The relaxation of statutory restrictions on the activity of thrift institutions has removed many of the obvious differences between banks and thrifts that led antitrust authorities to treat them as serving distinct markets. On the one hand, thrifts can now offer many services such as demand deposits that are analogous to those of commercial banks. In light of these similarities, the presence of thrift institutions may prevent banks from exercising market power since consumers and firms may consider the two types of institutions to be close substitutes. A high degree of substitutability between the two types of firms would suggest that antitrust authorities should consider them to be in the same product market for the purposes of merger evaluation.

[22] The Federal Deposit Insurance Corporation (www.fdic.gov//bank/statistical/index.html).

[23] The notion of the "service cluster" as the relevant product market for commercial bank mergers was established by the Supreme Court in *United States v. Philadelphia National Bank*, 374 U.S. 321 (1963).

[24] *United States v. Connecticut National Bank*, 418 U.S. 656 (1974).

On the other hand, thrifts still may not be regarded by consumers as close substitutes for banks. Consumers may simply not be aware of the broadening scope of services offered by thrifts, or they may prefer to conduct their financial transactions at one institution (Amel and Starr-McCluer 2002). The fact that banks still offer a broader range of services suggests that thrifts may not be actual or even potential competitors of banks despite similarities in certain product lines. It is also not clear that thrifts are taking full advantage of the relaxed restrictions on C&I lending. For example, Pilloff and Prager (1998) find that thrifts are not nearly as engaged in C&I lending as banks, although thrift C&I lending does tend to increase with commercial bank concentration suggesting the possibility of some substitution between the two.

Other papers have also investigated bank and thrift substitutability. Amel and Hannan (1999) find a relatively inelastic residual demand curve for bank deposits and interpret this as suggesting that banks and thrifts are not in the same product market. Cohen (2004), however, conducts non-nested hypothesis tests of some simple endogenous market structure models and rejects the hypothesis that banks and thrifts operate in totally indepdendent markets. Cohen and Mazzeo (2005) find banks and thrifts to be modest substitutes (though they are more concerned with differences across types of banks).

Antitrust treatment of thrifts when evaluating commercial bank mergers has evolved to reflect the changes in the regulatory environment and associated changes in the distinctions between banks and thrifts. Most merger analysis has continued to focus on calculation of HHIs for particular regional and product markets. The changing regulatory landscape has altered the product market definitions that various antitrust authorities consider. Of the four agencies responsible for oversight of bank mergers, the Office of the Comptroller (OCC) and the Federal Deposit Insurance Corporation (FDIC) give thrifts the same weight as banks in their HHI calculations. On the contrary, the Federal Reserve Board of Governors (FRB) usually counts 50% of thrift deposits in its initial HHI screens for bank and bank holding company mergers.[25] The Department of Justice (DOJ), which has the authority to review bank mergers separately from bank regulators, includes either 100% of thrift deposits or none at all depending on the extent to which the thrift is involved in C&I lending.

Through our empirical analysis, we intend to shed some light on this issue. At the very least, a finding that the presence of thrifts significantly alters the attractiveness of a market for banks would suggest the existence of a competitive link between the two types of firms.

[25] The FRB performs a detailed review of any bank mergers in which the implied post-merger HHI would increase by more than 200 to a level above 1800 in any market involved in the merger.

In other words, if banks tend to be less prevalent in markets with more thrifts all else equal (accounting for the endogeneity of the number of thrifts and banks in a market), then we would interpret such a finding as evidence that thrifts do influence the overall profitability of banks. This effect would reflect consumers viewing the two types of firms to be substitutes to some degree. In such a case, the relevant product market for a bank merger should probably account for thrifts in some way. Moreover, the difference in the competitive effect on bank entry across the two types of firms will provide some information about the way in which thrifts should be discounted relative to banks when considering the overall market.

Rather than providing specific guidelines for assessing the competitive effects of proposed mergers, our analysis yields information about an issue that is crucial for merger evaluation, namely definition of the appropriate product market. Our approach is a somewhat indirect way to examine this issue. The estimates of our model do not provide direct information about primitive factors such as cross-price elasticities that antitrust authorities should ideally consider when analyzing a merger. Instead, our conclusions about competitive effects are based on the implied impact of the presence of each type of firm on the overall market structure. Nonetheless, this approach provides information about competition between the two types of firms since we would expect to find no effect of thrifts on bank presence if the two operate in separate product markets. In addition, our approach focuses on generally defined competitive effects which provides a convenient way to broadly examine overall competition in the cluster of products.[26] Finally, our approach is attractive because we do not require detailed information on prices, quantities or other market outcomes to draw some inferences about competition between the two types of firms. Since price and quantity data for depository institutions are rarely disaggregated to the level of specific products and geographic markets, this feature of our approach is particularly attractive.[27]

Before discussing our data in more detail, we need to address one remaining market definition issue that we do not examine in this paper, namely the appropriate geographical market for merger analysis. In 1963, the Supreme Court ruled that competition between banks occurs primarily at a local level, and the focus of antitrust authorities historically

[26] Recent research has examined relationships between prices for specific services and different market structures. See, for instance, Tokel and Tokel (2000), Feinberg and Rahman (2001), Feinberg (2001) and Amel and Hannan (1999). The findings of this research has been mixed, but most excluding Amel and Hannan (1999) fail to account for endogeneity of market structure in their analysis.

[27] This aggregation problem in balance sheet data for financial institutions also precludes use of our approach to analyze how a bank's profits, for example, vary with market structure once the endogeneity of market structure has been taken into account.

followed the Court's guidelines.[28] However, the relaxation of interstate banking regulations as well as the increased use of information technology by consumers and businesses make less obvious the assumption that banking markets are local. Certainly, there are types of services involving markets that are much larger than most geographic markets as they are usually defined. Nonetheless, studies using data from the Federal Reserve's the Survey of Consumer Finances and the National Survey of Small Business Finances (Elliehausen and Wolken 1990 and 1992, Kwast, Starr-McCluer and Wolken 1997, and Amel and Starr-McCluer 2002) have found that (1) consumers and small businesses tend to obtain their financial services from nearby providers, and (2) consumers tend to obtain multiple financial services from the same firm. While this evidence does not provide information about substitutability of products across broadly defined markets, it is suggestive of some remaining localization of banking activity. Hence, most geographic market definition has continued to focus on some sort of regionally defined markets.

Our geographic market definition follows this current practice. If some financial services are still local in nature, we expect to be able to measure competitive effects in our analysis. Moreover, to the extent that national markets for some services exist, we expect national competition in these services to have a common effect on entry across all of our locally defined markets without significantly distorting the within-market competitive effects.

Our analysis considers only small banking markets which we define as labor market areas (LMAs) that are not part of a metropolitan statistical area (MSA) and have less than 100,000 inhabitants. Small LMAs are determined by the Bureau of Labor Statistics. The BLS defines a LMA as an "economically integrated geographic area within which individuals can reside and find employment within a reasonable distance or can readily change employment without changing their place of residence."[29] LMAs are built up from counties based on commuting patterns. If at least fifteen percent of a county's workers commutes to a contiguous county, then the two counties are grouped into an LMA. Further iterations considering all counties contiguous to the newly formed LMA are performed until all combinations are exhausted.

We focus on small markets for two reasons. First, almost all antitrust concerns associated with bank mergers arise in these smaller markets. Second, considering markets with a larger set of possible outcomes (i.e., combinations of banks and thrifts) significantly increases the set of equilibria to the point of making the problem computationally prohibitive.

[28] *United States v. Philadelphia National Bank*, 374 U.S. 321 (1963).
[29] http://www.bls.gov/lau/lmadirectory2003.pdf

Our dataset contains 1,874 small LMA markets in the United States.[30] Table 1 provides a list of the explanatory variables that we gathered from the Census, the Bureau of Economic Analysis, and the Census of Agriculture for these LMA markets. We include the number of people, farms and business establishments in our analysis to account for differences in the size of the markets. Occupancy rate is the number of occupied housing units divided by the total number of housing units in a market. We include this variable, along with per capita income, to reflect overall differences in economic conditions across the markets. We obtained information on bank and thrift presence at the county level in 2000 from the FDIC Summary of Deposits and the Office of Thrift Supervision's (OTS) Branch Office Survey. We aggregated all county-level data up to the level of the LMAs defined by the Bureau of Labor Statistics.

As discussed in the previous section, our data also contain variables that describe regulations applicable to different types of depository institutions. In some cases, these variables represent historical regulations that have recently been altered. In these cases, we include these variables to allow for the possible impact of historical evolution of the industry under these regulations on the market structure in 2000.

Two of our regulatory variables pertain to thrifts. Thrifts can be chartered as either savings and loans (S&Ls) or savings banks. In either case, a thrift can obtain a charter from the federal government through the OTS. However, some states also issue charters for thrift institutions. In our data, we have a variable indicating whether a state issues S&L charters and another variable indicating whether it issues savings bank charters. Since application for a state charter provides an alternative route for setting up a thrift and also involves different oversight, we view these variables as market characteristics that potentially affect the cost of operating a thrift.

Our data also contain a number of variables describing regulations on bank operations. Each state regulates the number of branches that a bank can operate within its boundaries. For example, a state could permit only a single branch per bank under a "unit banking" policy or could permit branches to be opened "locally." Our data contain an indicator variable for whether or not a state permitted unrestricted statewide branching in 1990.

Historically, each state also regulated the extent to which banks situated in other states were allowed to operate within its boundaries. In the 1990s, these regulations involved one

[30] When compiling these data, we dropped LMAs in Alaska and Hawaii, those that covered more than one state due to the presence of differences in regulations across states, and those for which county-level data were missing or reported as unreliable.

of three basic forms of reciprocity requirements that we term national bank holding companies (NATL BHC), national reciprocal bank holding companies (NATL RECIP BHC), and reciprocal bank holding companies (RECIP BHC). The first of these policies involved a state placing no reciprocity restrictions on operations of bank holding companies. This regulation would effectively permit unrestricted entry of banks that were headquartered in other states. Under the second policy, a state employed a reciprocal requirement which allowed a bank holding company from any state to set up operations in Illinois, for example, only if a bank from Illinois could also operate in the home state of the entrant into Illinois. Lastly, a state could permit entry of out-of-state banks under specific reciprocity arrangements. For example, Iowa permitted entry of banks that were headquartered in Illinois, Minnesota, Missouri, Nebraska, South Dakota and Wisconsin.

The Riegle-Neal Interstate Banking and Branching Efficiency Act of 1994 limited the ability of states to regulate entry of out-of-state banks. The Riegle-Neal Act permitted bank holding companies to acquire banks in any state as of late 1995. In mid-1997, the Act allowed bank holding companies to branch across state lines.[31] Hence, many of the historical restrictions on entry reflected in state regulations are no longer in effect. As noted earlier, we include these variables to allow for the possibility that these regulations influenced the evolution of the industry in a market and had a persistent effect on the market structure.

Table 2 provides a tabulation of the bank and thrift configurations that we observe in the data. Tables 3 and 4 provide summary statistics on the variables in our data by number of banks and thrifts respectively.

Estimation Results

In this section, we describe the results of a number of different estimation procedures including one reflecting a sequential move assumption and three involving different specifications of the objective function for the bounds approach. To reiterate, we employ the following functional form for the payoff functions

$$\pi_t \left(N_1, N_2, X_{tm}, \varepsilon_{tm}; \theta_t\right) = \beta_{t0} + X_m \beta_t + Z_{tm} \gamma_t + \Delta_{t1} N_1 + \Delta_{t2} N_2 + \varepsilon_{tm}. \tag{14}$$

Throughout, we assume that the unobservables are standard normal random variables that are uncorrelated across thrifts and banks.[32] As a caveat, estimated coefficients must be

[31] However, state law continues to control branching within a state's borders.

[32] As is standard in threshold models, the scale of the error terms is not identified. Hence, we normalize the variances to one. In principle, we can estimate the model permitting correlation between the unobservables, but we currently restrict that correlation to be zero.

interpreted with care in all models due to the reduced form nature of the payoff function and the fact that the parameters are only estimated up to an unknown positive scale factor.

We begin by estimating a version of the model reflecting the sequential move structure developed by Mazzeo (2002). As noted earlier, the sequential move assumption implies a unique subgame perfect equilibrium so that we can use standard maximum likelihood techniques to estimate the parameters of the payoff function. Since the regions of integration are somewhat irregular, we simulate the probabilities generated by the model for each of the observed market structures. As discussed in Stern (1997), this estimator will be consistent as the number of simulated draws goes to infinity.

Table 5 presents the maximum likelihood estimates of the payoff functions using the sequential move assumption. One of the notable features of these estimates is the statistically insignificant coefficient on population in the bank payoff function. This finding is likely an artifact of the high correlation between the number of establishments and population (0.92). Similarly, the estimate on the S&L variable along with the intercept in the thrift payoff function reflects the large proportion of markets that fall in states that issue savings and loan charters.

Notably, the coefficients on the regulatory variables for banks are all negative. According to these estimates, a market with reciprocal requirements for specific states is more attractive than a market with a national reciprocal policy. The latter is in turn more attractive than a market in a state with no reciprocity requirements. One interpretation of these results is that the reciprocity requirements reflect historical barriers to entry. States that had strong reciprocity requirements effectively limited the possibility of out-of-state entrants into its markets. According to the estimates, markets with a history of controls on out-of-state entry are more attractive than markets with more lenient entry policies. Despite the fact that these restrictions are no longer in force, they appear to still have a significant impact on bank presence in our markets.

For both types of firms, additional competitors are found to have a negative effect on profitability. However, in both cases, this effect is almost entirely confined to firms of the same type since the coefficients on opposite types, Δ_{TB} and Δ_{BT}, are generally small and statistically not different from zero. In other words, while the presence of an additional bank does decrease the attractiveness of the market for other banks as reflected in the negative estimate for Δ_{BB}, an additional thrift has little to no impact on bank profitability. Taken at face value, these estimates suggest that thrifts and banks do in fact operate in separate product markets despite the similarities in many of their services.[33]

To examine the robustness of these findings, we now turn to estimates based on our general model. In principle, our model should yield consistent estimates of the payoff function parameters regardless of the actual entry process, but will yield less efficient estimates relative to a correctly specified model that accounts for the way in which firms enter a market. Hence, if the sequential move assumption is correct, our estimates should not differ substantially from those in Table 5.

Table 6 presents results from estimation of the general model. The three sets of results differ depending on the weight given to different outcomes for each observed value of the covariates in the model. As noted earlier, the first set of results uses all of the possible outcomes whereas the second results use only the observed outcome for each market. The third results weight the various outcomes by their estimated empirical probabilities. In this table, we report the value of the parameters that minimize the sample objective function. In addition to these point estimates, we also report bounds estimates based on the approach of Chernozhukov, Hong and Tamer (2003). The approach used to compute these bounds closely follows Ciliberto and Tamer (2003).

Looking across the three sets of results, there do not appear to be very substantive differences in the implied estimates. These similarities are apparent for both the reported point estimates as well as the estimated bounds on the parameters. Relative to the estimates from the sequential move model, there are a few substantial differences in the estimates for the covariates in the model. Specifically, the full model implies a positive impact of state branching on the profitability of banks whereas the sequential move model yielded a negative estimate. Similarly, while the sequential move model implied a substantial positive coefficient on the savings and loan variable for thrifts, the results are less clear for the full model.

The most striking differences between the sequential move estimates and the full model occur in the coefficients reflecting the competitive effects. In the sequential move model, the cross-firm effects were typically estimated to be small. For example, the sequential move estimates imply that the presence of a bank does not influence the attractiveness of a market for a thrift. While those estimates suggest that a bank's profitability is affected by the presence of thrifts, that effect is relatively small and not precisely estimated. In

[33] These findings mirror the results of Mazzeo (2002) in his initial study of entry into motel markets. Various other applications of the sequential move model (e.g. Dranove, Gron and Mazzeo forthcoming, Greenstein and Mazzeo 2003) have similarly found negligible competitive effects across firms that exhibit discrete differences from one another.

particular, the estimates indicate that the competitive effect of a thrift for a bank is about 17% of the impact of an additional bank.

The latter finding is roughly supported by the full model, but the former finding is not. For each model, Table 7 presents the implied impact of an additional competitor of a different type relative to the impact of a same type competitor for each type of firm. In other words, Table 7 presents the ratio $\frac{\Delta_{TB}}{\Delta_{TT}}$ for thrifts and $\frac{\Delta_{BT}}{\Delta_{BB}}$ for banks. The first provides the impact of an additional bank on thrift profits relative to the impact of an additional thrift.[34] This table provides point estimates of these ratios as well as 95% confidence intervals. For banks, this table indicates that the relative impact of an additional thrift ranges from about 11% to 20%. The magnitude of this relationship between the coefficients is roughly the same across the various estimation results. However, the implications for thrifts are substantially different across the models. Whereas the sequential move model indicates that banks are effectively irrelevant for a thrift, the full model suggests that an additional bank is roughly 50% to 60% of an additional thrift. In other words, the competitive effect of one additional bank from a thrift's point of view is around 1/2 the impact of facing an additional thrift competitor.

The estimated asymmetries in the competitive effects across banks and thrifts are intriguing. If a market were to become more attractive through, for example, an increase in size, the estimates of the bank payoff function suggest that banks would smoothly enter as the market grew sufficiently large. A minor adjustment to this entry pattern would occur in the event of a thrift entry, but such an event is largely irrelevant for potential bank entrants. On the other hand, increased market attractiveness accompanied by bank entry would substantially influence the prospects of new thrifts. All else equal, a market would have to grow disproportionately in order to support additional thrifts in light of the likely increase in bank activity.

These asymmetries have a number of implications. First, the practice of discounting thrifts when screening markets subject to a potential bank merger does not appear to be a terribly inappropriate first approximation as the observed entry behavior of banks indicate that thrifts exert little influence on banks. More generally, these findings are suggestive about the nature of the firms in this industry. In particular, industry observers often speculate that thrifts enter to serve market segments for whom banks do not provide sufficient service. The nature of these specialized segments, however, may be such that thrifts re-

[34] These types of relative measures for competitive effects are appealing because it is unclear how magnitudes should be interpreted given the reduced form nature of the model.

quire disproportionately attractive markets to offset bank competition. While our estimates cannot definitively uncover the underlying reasons for these differences between banks and thrifts, they are suggestive of such effects.

Conclusion

In this paper, we present and estimate a relatively simple model of market structure determination with discrete product differentiation. Under reasonable but fairly weak conditions on the profits required to yield different market structures as equilibria, we document the presence and potential extent of multiple equilibria in this framework. As in other applications involving discrete games, multiple equilibria complicates estimation of the model due to the inability to obtain exact probability statements for different outcomes from the model. To deal with this problem, we consider two solutions. The first involves an application of Mazzeo's (2002) sequential move assumption which yields a unique equilibrium for each set of payoff values. However, we are concerned about the potential bias that this approach could introduce if the assumption about the order of entry is incorrect. Consequently, our second solution involves applying the approach of Ciliberto and Tamer (2003) in which we use the model to generate bounds on the outcome probabilities. A modified minimum distance estimation approach then allows us to use these bounds to draw inferences about factors that influence market structures, most notably the importance of discrete product differentiation. This approach allows us to perform the estimation without utilizing any equilibrium selection mechanism in regions of multiplicity.

In our application, we consider the determination of market structure in 1,874 rural banking markets. Historically, two different types of institutions, namely banks and thrifts, have provided financial services in such markets. However, recent regulatory changes have potentially diminished the importance of differences across these two types of firms, a development that could have implications for issues such as market definition in antitrust settings. Our analysis sheds light on this issue by examining the extent to which the presence of one type of firm appears to be influenced by the presence of the other type. While our initial estimates based on a sequential move assumption indicate that competitive effects are largely confined to firms of the same type, our full model suggests that some cross-effects do exist. Notably, we find asymmetries which suggest that thrifts are substantially influenced by bank presence whereas the converse effect, while present, is not nearly as large.

One interesting finding from our estimation is the difference between the results based on the probability bounds and those based on the sequential move assumption. An inherent difficulty in models with multiple equilibria is the fact that some outcome must obtain in the regions of multiplicity and, thus, some selection rule must exist that yields an outcome in those cases. An open question is then the extent to which the data can reject different equilibrium selection rules. Our application provides an example of this issue. In our case, the results using the sequential move assumption differ somewhat from those found using an approach that should be consistent regardless of the underlying selection rule. This finding suggests that, not only is the bounds approach informative about the underlying primitives, but it may also provide information about the "true" equilibrium selection mechanism.

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Table 1: Explanatory variables

Variable	Description
FARMS	Number of farms
EST	Number of business establishments
POP	Total population
PCI	Per capita income
OCC	Residential occupancy rate
S&L	= 1 if state grants savings and loan charters
SAVINGS	= 1 if state grants savings bank charters
STATE BRANCHING	= 1 if state allowed unrestricted statewide branching in 1990
NATL BHC	= 1 if state permitted bank subsidiary operations without any reciprocity requirements in 1993
NATL RECIP BHC	= 1 if state permitted bank subsidiary operations under a general reciprocity requirement with headquarters state of bank holding company in 1993
RECIP BHC	= 1 if state permitted bank subsidiary operations under reciprocity with specific headquarters states of bank holding company in 1993

Table 2: Market Structures of Banks and Thrifts in 2000

		Number of Banks									
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**All**
Number of Thrifts	**0**	13	111	195	222	167	119	99	48	72	1046
	1	4	14	60	75	90	94	67	60	114	578
	2	0	6	12	16	23	27	30	20	48	182
	3	0	0	1	3	13	6	4	6	35	68
	All	17	131	268	316	293	246	200	134	269	1874

Souce: FDIC Summary of Deposits and the OTS's Branch Office Survey

Table 3: Market Characteristics by Bank Market Structure

Variable		All	Number of Banks 0	1	2	3	4	5	6	7	8
FARMS	**mean**	538.97	11.33	136.49	272.46	388.71	457.81	587.39	668.20	785.24	1035.75
	std dev	450.44	78.21	129.63	222.89	264.11	292.72	366.45	422.15	443.69	580.99
EST	**mean**	615.17	119.80	166.39	268.43	371.89	533.29	659.83	758.07	998.74	1247.30
	std dev	504.88	47.72	72.93	137.45	200.01	286.10	342.33	420.01	545.04	659.62
POP	**mean**	23171	3074	4218	9705	14144	21181	25801	28985	37572	45959
	std dev	19834	3114	3525	6632	9855	13785	15693	18334	22769	22505
PCI	**mean**	21.00	20.71	19.08	19.56	20.28	20.65	21.28	22.12	22.43	22.83
	std dev	3.99	11.27	4.64	4.00	3.49	3.82	3.13	4.36	3.15	3.00
OCC	**mean**	0.83	0.64	0.75	0.81	0.82	0.84	0.85	0.85	0.88	0.88
	std dev	0.10	0.21	0.13	0.09	0.09	0.08	0.08	0.08	0.06	0.08
STATE BRANCHING	**mean**	0.52	0.82	0.50	0.63	0.52	0.55	0.54	0.50	0.49	0.36
NATL BHC	**mean**	0.22	0.53	0.40	0.30	0.24	0.22	0.18	0.15	0.18	0.09
NATL RECIP BHC	**mean**	0.37	0.35	0.28	0.40	0.33	0.37	0.41	0.42	0.35	0.39
RECIP BHC	**mean**	0.41	0.12	0.32	0.30	0.43	0.41	0.41	0.43	0.47	0.52
Number		1876	17	131	268	316	293	246	200	134	269

Table 4: Market Characteristics by Thrift Market Structure

Variable			Number of Thrifts			
		All	**0**	**1**	**2**	**3**
FARMS	**mean**	538.97	412.74	650.41	782.62	881.43
	std dev	450.44	345.19	470.57	585.25	587.52
EST	**mean**	615.17	434.36	720.95	989.04	1496.73
	std dev	504.88	354.43	489.02	553.46	710.00
POP	**mean**	23171	16511	27031	37415	54589
	std dev	19834	15163	19230	22050	23106
PCI	**mean**	21.00	20.28	21.50	22.69	23.22
	std dev	3.99	4.29	3.26	3.51	3.05
OCC	**mean**	0.83	0.82	0.85	0.86	0.86
	std dev	0.10	0.10	0.09	0.08	0.10
SAVINGS	**mean**	0.49	0.47	0.49	0.56	0.62
S&L	**mean**	0.98	0.96	0.99	0.99	0.98
Number		1874	1046	578	182	68

Table 5: Sequential Move Estimates of Payoff Functions

Firm Type	Variable	Estimate	SE	95% CI Lower	95% CI Upper
Thrift	**Intercept**	-0.085	0.278	-0.6301	0.4594
	FARMS	0.1932	0.0386	0.1175	0.2689
	EST	0.3434	0.0516	0.2423	0.4446
	POP	0.1689	0.0614	0.0486	0.2892
	PCI	0.1588	0.0324	0.0952	0.2224
	S&L	1.0831	0.2019	0.6875	1.4788
	SAVINGS	0.0114	0.0581	-0.1024	0.1253
	D_{TT}	-1.092	0.0319	-1.1551	-1.03
	D_{TB}	-0.0116	0.0701	-0.0857	0.0624
Bank	**Intercept**	4.0681	0.1049	3.8625	4.2736
	FARMS	0.713	0.0271	0.6599	0.7661
	EST	0.9775	0.0833	0.8142	1.1407
	POP	0.0681	0.0785	-0.0857	0.2219
	PCI	0.1621	0.0281	0.1069	0.2172
	STATE BRANCHING	-0.282	0.0573	-0.3952	-0.1704
	NATL BHC	-0.546	0.078	-0.6989	-0.3932
	NATL RECIP BHC	-0.1949	0.0599	-0.3123	-0.0775
	D_{BB}	-0.7179	0.0136	-0.7446	-0.6913
	D_{BT}	-0.1245	0.0701	-0.2618	0.0128
Loglik		-4971.01			
N		1874			

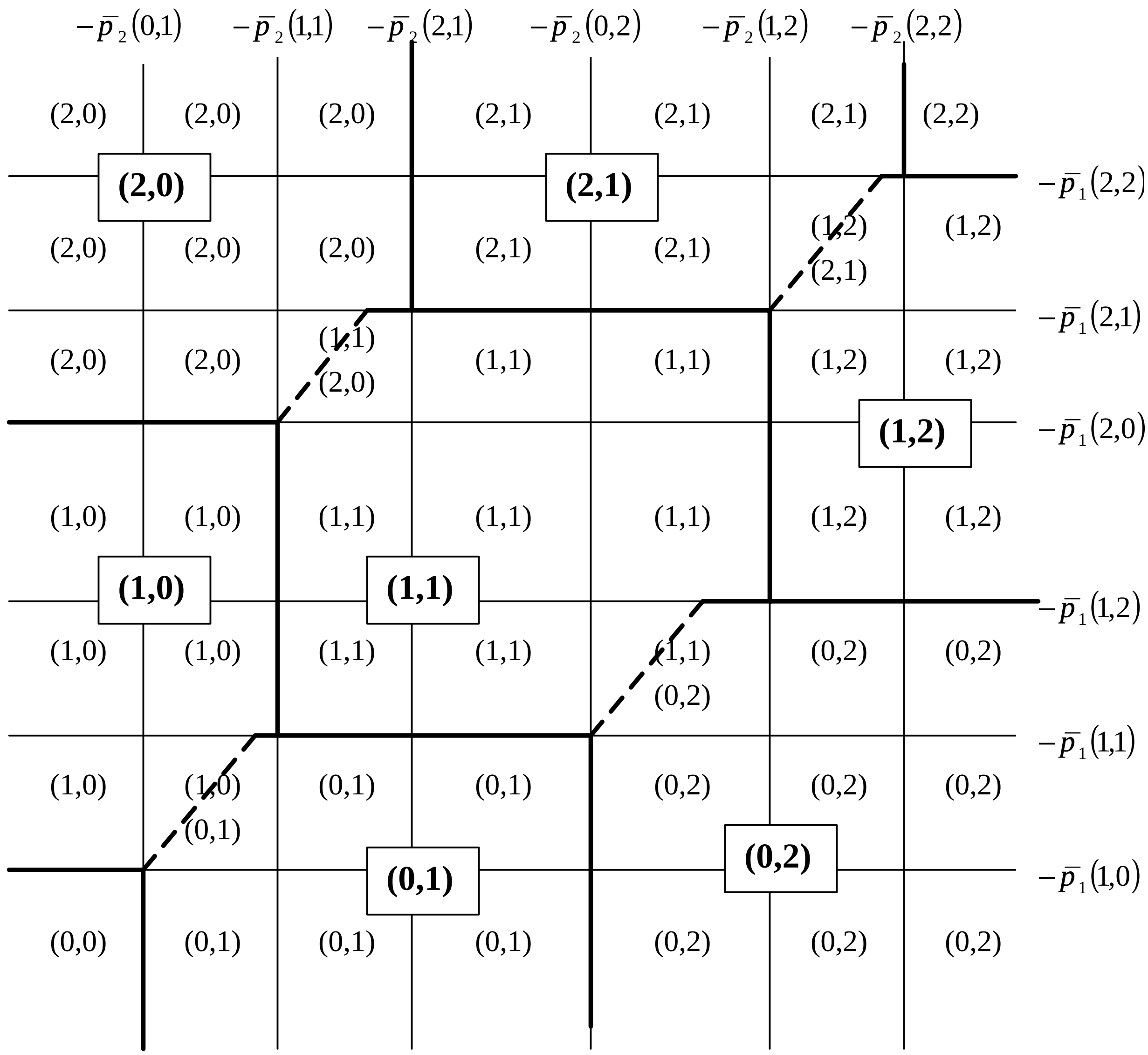
Table 6: Bounds Estimates of Payoff Functions

		(1) Unweighted			(2) Observed outcomes			(3) Weighted by empirical likelihood		
			95% Bounds			95% Bounds			95% Bounds	
Firm Type	**Variable**	**Estimate**	**Lower**	**Upper**	**Estimate**	**Lower**	**Upper**	**Estimate**	**Lower**	**Upper**
Thrift	**Intercept**	-0.0616	-0.0647	0.0396	-0.0592	-0.0953	0.0347	-0.0053	-0.0793	0.1076
	FARMS	0.8226	0.7298	0.8638	0.7883	0.6699	1.0343	0.9828	0.7612	1.1001
	EST	1.2146	1.1059	1.3125	1.2577	0.9984	1.3380	1.0207	0.9060	1.1510
	POP	0.13	0.1142	0.1428	0.0758	-0.0463	0.1887	0.1690	0.0470	0.2820
	PCI	0.108	0.0971	0.229	0.1095	0.0560	0.2080	0.0722	-0.0289	0.1706
	S&L	-0.0264	-0.0278	0.0792	-0.0240	-0.0992	-0.0217	-0.0355	-0.1348	0.0407
	SAVINGS	-0.0038	-0.0042	0.0115	-0.0035	-0.0538	0.1047	-0.0037	-0.0891	0.1045
	D_{TT}	-0.7334	-0.9494	-0.6535	-0.9992	-1.1625	-0.8799	-1.1051	-1.3687	-0.9690
	D_{TB}	-0.4377	-0.4996	-0.413	-0.5153	-0.6707	-0.4707	-0.6218	-0.7456	-0.5044
Bank	**Intercept**	3.2117	3.1218	3.3754	4.0385	3.6438	4.2442	3.9828	3.6248	4.3884
	FARMS	1.0185	0.8991	1.0694	1.1716	0.9884	1.3483	1.2831	1.0825	1.4785
	EST	1.4544	1.3827	1.6118	2.2005	1.9176	2.4386	2.0304	1.7395	2.4698
	POP	-0.1337	-0.1408	-0.058	-0.1020	-0.1126	-0.0070	-0.0751	-0.1183	0.0199
	PCI	0.0456	0.0422	0.0875	0.0341	-0.0476	0.0399	-0.0001	-0.0842	0.0461
	STATE BRANCHING	0.1342	0.0129	0.1463	0.1256	0.1083	0.2456	0.1715	0.0684	0.2915
	NATL BHC	-0.469	-0.5199	-0.4307	-0.3593	-0.4584	-0.3299	-0.4358	-0.5240	-0.3118
	NATL RECIP BHC	-0.2307	-0.2602	-0.2044	-0.2466	-0.3085	-0.1294	-0.2310	-0.3520	-0.1138
	D_{BB}	-0.8294	-0.8501	-0.803	-1.0501	-1.0950	-0.9533	-1.0495	-1.1091	-0.9527
	D_{BT}	-0.1664	-0.1795	-0.0497	-0.1253	-0.1919	-0.0463	-0.1825	-0.2849	-0.1034
N		1876								

Table 7: Estimated Ratios of Competitive Effects

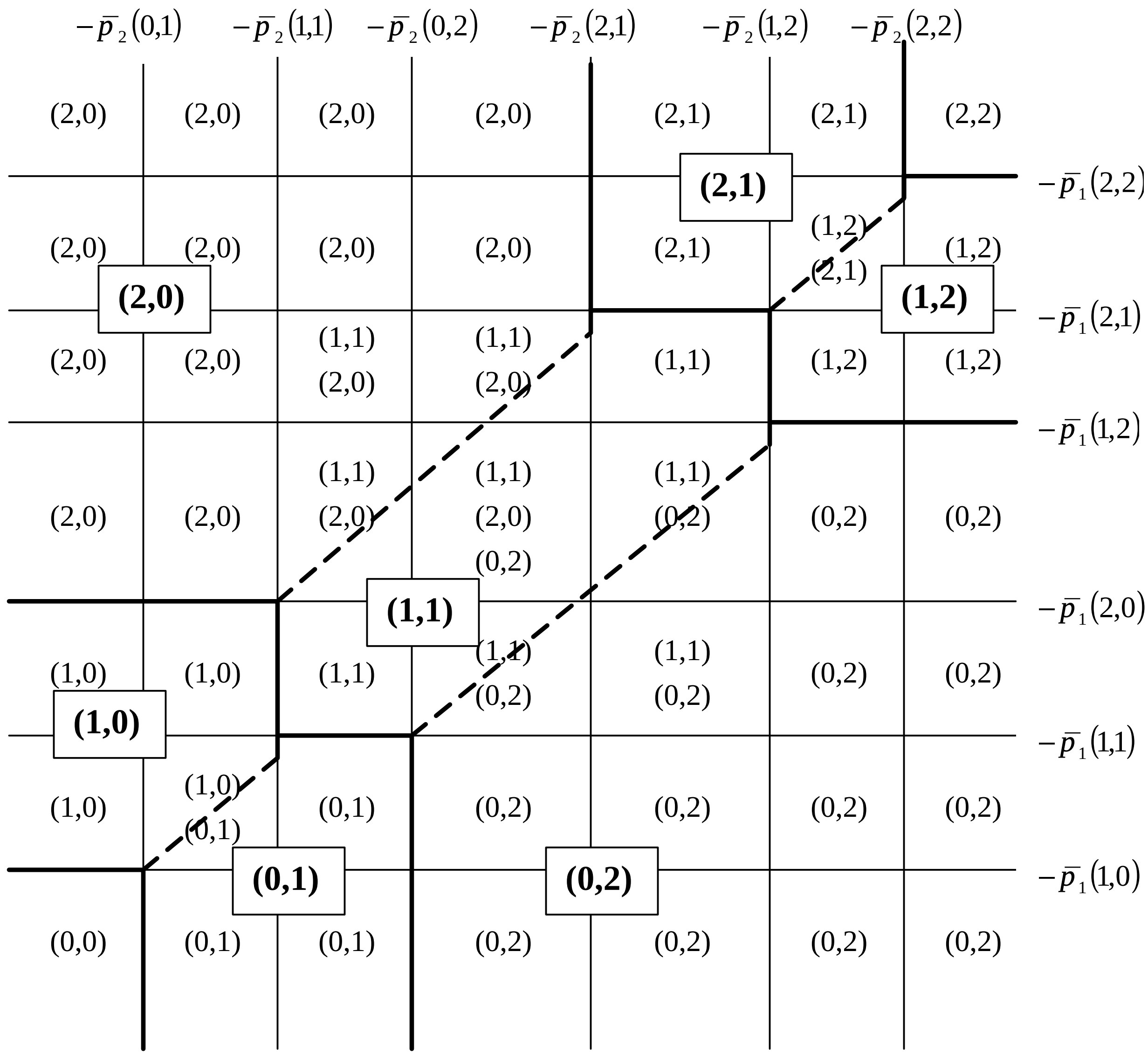
	Effect on Bank Profits			Effect on Thrift Profits		
	Estimate	95% CI for Ratio of Thrift Effect to Bank Effect		Estimate	95% CI for Ratio of Bank Effect to Thrift Effect	
Sequential Move	17.34%	-1.68%	36.36%	1.06%	-5.70%	7.83%
Modified Minimum Distance Unweighted	20.06%	6.19%	21.42%	59.68%	45.20%	76.46%
Modified Minimum Distance Weighted by Likelihood	17.39%	10.09%	27.54%	56.27%	39.11%	71.26%
Modified Minimum Distance Observed Outcomes	11.93%	4.51%	18.55%	51.57%	42.88%	66.47%

Figure 1: Illustration of simple multiplicity



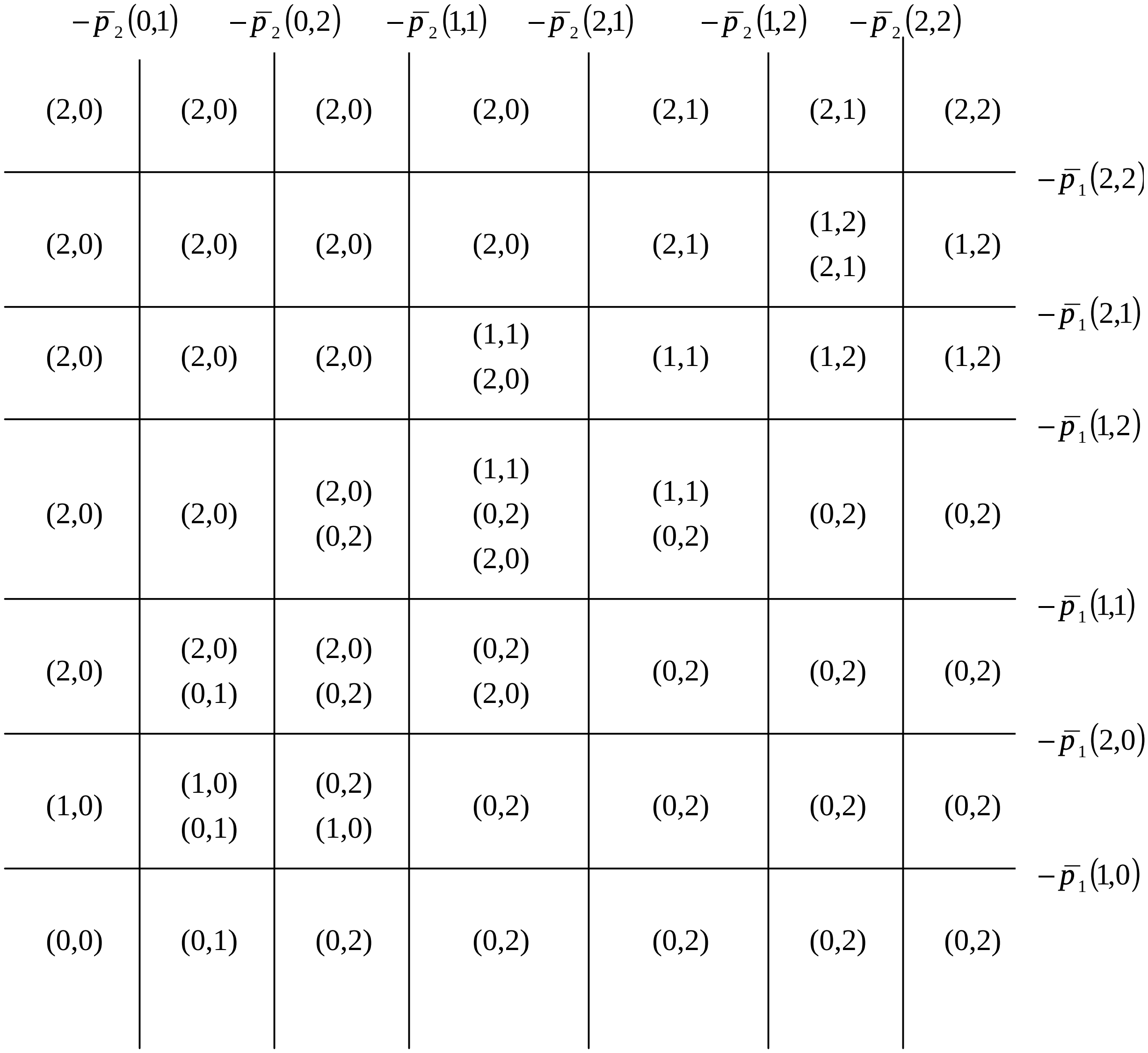
Note: Graph depicts e_1 values on the vertical axis and e_2 values on the horizontal axis. Entries in each region are the configurations that are consistent with the basic equilibrium concept. Dashed lines represent restrictions imposed by sequential move game while bold solid and dashed lines provide regions associated with each configuration in the sequential move game as indicated by the boxed configurations.

Figure 2: Illustration of severe multiplicity



Note: Graph depicts e_1 values on the vertical axis and e_2 values on the horizontal axis. Entries in each region are the configurations that are consistent with the basic equilibrium concept. Of particular note is the center region in which the configurations (1,1), (2,0) and (0,2) are all equilibria. Dashed lines represent restrictions imposed by sequential move game while bold solid and dashed lines provide regions associated with each configuration in the sequential move game as indicated by the boxed configurations. Note that this figure differs from Figure 1 in that it assumes $\bar{p}_2(0,2) > \bar{p}_2(2,1)$ and similarly for firm 1.

Figure 3: Illustration of multiplicity where the total number of firms is not unique



Note: Graph depicts e_1 values on the vertical axis and e_2 values on the horizontal axis. Entries in each region are the configurations that are consistent with the basic equilibrium concept. Of particular interest are the regions where (2,0) and (0,1) or (0,2) and (1,0) are both equilibria. Note that this figure differs from Figures 1 and 2 in that it assumes $\bar{p}_2(0,2) > \bar{p}_2(1,1)$ and similarly for firm 1 (so that assumptions A3 and A4 are violated). The sequential move game is not applicable in this situation.