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Switching Costs in Network Industries

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Preliminary: comments welcome

Abstract

In network industries, switching costs have two opposite effects on the tendency towards market tipping. First, the fat-cat effect makes the larger firm price less aggressively and lose consumers to the smaller firm. This effect tends to prevent tipping. Second, the network-solidifying effect reinforces network effects by making a network size advantage longer-lasting and hence more valuable, thus intensifying price competition when networks are of comparable size. This effect tends to cause tipping. I find that when switching costs are high, the fat-cat effect dominates and an increase in switching costs can change the market from a tipping equilibrium to a sharing equilibrium. When switching costs are low, the network-solidifying effect dominates and an increase in switching costs can change the market from a sharing equilibrium to a tipping equilibrium. Policy intervention to remove switching costs in network industries may substantially reduce the likelihood of market tipping.

1 Introduction

A prominent feature in many network industries is the existence of switching costs: consumers can switch between networks but it is costly (in terms of money and/or effort) for them to do so. Examples include PC operating systems, video game consoles, cell phone services, etc. While there have been many studies that analyze network effects and switching costs separately, few have looked at them jointly, and it is unclear whether the findings thus far can be applied to markets in which those two factors coexist.

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To better understand the effects of switching costs in network industries, this paper builds a dynamic oligopolistic model that incorporates both network effects and switching costs. Firms dynamically optimize. A Markov perfect equilibrium is numerically solved for, and I assess the effects of switching costs on the frequency with which market tipping occurs. In ongoing work, I am also investigating the price and welfare effects of switching costs in such industries.

I find that results are markedly different when we go from a model with only switching costs to one with both network effects and switching costs. In particular, the literature on switching costs without network effects finds that switching costs have a fat-cat effect, which makes the larger firm price less aggressively and lose consumers to the smaller firm. This effect tends to prevent market tipping, and as a result, markets with switching costs tend to be stable (Beggs and Klemperer (1992), Chen and Rosenthal (1996), Taylor (2003)). When network effects are incorporated into the analysis, switching costs also have a network-solidifying effect, which reinforces network effects by making a network size advantage longer-lasting and hence more valuable, thus intensifying price competition when networks are of comparable size. This effect tends to cause tipping. I find that when switching costs are high, the fat-cat effect dominates and an increase in switching costs can change the market from a tipping equilibrium to a sharing equilibrium. When switching costs are low, the network-solidifying effect dominates and an increase in switching costs can change the market from a sharing equilibrium to a tipping equilibrium. Such a non-monotonic relationship can not be revealed without taking account of the interaction between network effects and switching costs. The finding suggests that policy intervention to remove switching costs in network industries may substantially reduce the likelihood of market tipping.

For a survey of the literature on switching costs and the literature on network effects, see Farrell and Klemperer (2007); see also Klemperer (1995) and Economides (1996). As discussed above, prior studies typically focus on one factor and abstract from the other. In particular, the literature on switching costs typically assumes zero network effects, and the literature on network effects typically assumes infinite switching costs (complete lock-in). Two exceptions are Doganoglu and Grzybowski (2005) and Suleymanova and Wey (2008).

Doganoglu and Grzybowski (2005) use a two-period differentiated-products duopoly model to study the effects of switching costs and network effects on demand elasticities and prices. My framework differs from theirs in that I work with an infinite-horizon model, which avoids the unrealistic beginning-of-game and end-of-game effects, and allows me to investigate both the short-run and the long-run industry dynamics. For example, in the presence of switching costs, in an infinite-horizon model firms have both the investment motive and the harvesting motive in every period, whereas in a two-period model they do not.

Suleymanova and Wey (2008) use a Bertrand duopoly model to study market outcomes under network effects and switching costs. They find that the equilibrium outcome (monopoly versus market sharing) critically depends on the ratio of switching costs to network effects. They assume that all agents are myopic whereas in my model firms are forward-looking and optimize dynamically. Such modeling allows me to explore firms' dynamic pricing incentives. For example, low introductory pricing (sometimes below cost) to fight for future dominance can only happen in a dynamic setting.

The model is described in Section 2. Markov perfect equilibria of the model are reviewed in Section 3, and the effects of switching costs on the tendency towards market tipping are explored in Section 4. Section 5 concludes.

2 Model

This section describes a dynamic oligopolistic model of markets with network effects and switching costs. Since the objective is to provide some general insights about the effects of switching costs in network industries, I do not tailor the model to a specific product. Instead, a more generic model is developed to capture the key features of many markets characterized by network effects and switching costs.

2.1 State Space

The model is cast in discrete time with an infinite horizon. There are $N \geq 2$ single-product price-setting firms, who sell to a sequence of buyers with unit demands. Firms' products are referred to as the inside goods. There is also an outside good ("no purchase"), indexed 0. At the beginning of a period, a firm is endowed with an installed base which represents consumers who have purchased its product in the past. Let $b_i \in \{0, 1, ..., M\}$ denote the installed base of firm i where M is the bound on the sum of the firms' installed bases. $b_0 = M - b_1 - ... - b_N$ is taken as the outside good's "installed base", though it does not offer network benefits. The industry state is $b = (b_1, ..., b_N)$, with state space $\Omega = \{(b_1, ..., b_N) | 0 \leq b_i \leq M, \, i = 1, ..., N; \, b_1 + ... + b_N \leq M\}$.

2.2 Demand

Demand in each period comes from a randomly selected consumer who chooses one among the $N+1$ goods. Let $r \in \{0, 1, ..., N\}$ denote the *type* of this consumer, that is, the good that has her loyalty. r is stochastic and I assume r is distributed according to $\Pr(r = j|b) = b_j/M$, $j = 0, 1, ..., N$. The utility that a type r consumer gets from buying good i is

$$v_i + \mathbf{1}(i \neq 0)\theta g(b_i) - p_i - \mathbf{1}(r \neq 0, i \neq 0, i \neq r)k + \epsilon_i.$$

Here v_i is the intrinsic product quality, which is fixed over time and is common across firms: $v_i = v$, $i = 1, ..., N$. Since the intrinsic quality parameters affect demand only through the expression $v - v_0$, without loss of generality I set $v = 0$, but consider different values for v_0.

The increasing function $\theta g(.)$ captures network effects, where $\theta \geq 0$ is the parameter controlling the strength of network effect. There are no network effects associated with the outside good. The results reported below are based on linear network effects, that is, $g(b_i) = b_i/M$. I have also allowed g to be convex, concave, and S-shaped, and the main results are robust.

p_i denotes the price for good i. The price of the outside good, p_0, is always zero.

The nonnegative constant k denotes switching cost, and is incurred if the consumer switches from one inside good to another. A consumer who switches from the outside good to an inside good incurs a start-up cost, which is normalized to 0. Increasing the start-up cost above 0 has the effect of lowering the inside goods' intrinsic quality relative to the outside good's.

ϵ_i is the consumer's idiosyncratic preference shock. $(\epsilon_0, \epsilon_1, ..., \epsilon_N)$ and r are unknown to the firms when they set prices.

The consumer buys the good that offers the highest current utility. I am then assuming that consumers make myopic decisions. Such a parsimonious specification of consumers' decision-making allows rich modeling of firms' prices and industry dynamics. Allowing consumers to be forward-looking with rational expectations in the presence of both network effects and switching costs is an important but challenging extension of the current work.

Assume ϵ_i, $i = 0, 1, ..., N$ is distributed type I extreme value, independent across products, consumers, and time. The probability that a type r consumer buys good i is then

$$\phi_{ri}(b, p) \equiv \frac{\exp\left(v_i + \mathbf{1}(i \neq 0)\theta g(b_i) - p_i - \mathbf{1}(r \neq 0, i \neq 0, i \neq r)k\right)}{\sum_{j=0}^{N} \exp\left(v_j + \mathbf{1}(j \neq 0)\theta g(b_j) - p_j - \mathbf{1}(r \neq 0, j \neq 0, j \neq r)k\right)},$$

where b is the vector of installed bases and p is the vector of prices.

2.3 Transition Probabilities

Let $\Delta(b_i)$ denote the probability that the installed base of firm i depreciates by one unit, where $\Delta(b_i) = 1-(1-\delta)^{b_i}$ and $\delta \in [0, 1]$ is the rate of depreciation. Thus the likelihood that a firm's installed base depreciates increases with the size of its installed base. One motivation for this specification is that if b_i products were to independently die with probability δ, then the probability of at least one dying is $1 - (1 - \delta)^{b_i}$. The number of deaths in a period is then capped at one as a simplifying approximation.

Let $q_i \in \{0, 1\}$ indicate whether or not firm i makes the sale. Its installed base changes according to the transition function

$$\Pr(b_i'|b_i, q_i) = \begin{cases} 1 - \Delta(b_i) & \text{if} \quad b_i' = b_i + q_i, \\ \Delta(b_i) & \text{if} \quad b_i' = b_i + q_i - 1. \end{cases}$$

If the joint outcome of the sale and the depreciation results in an industry state outside of the state space, the probability that would be assigned to that state is given to the nearest state(s) on the boundary of the state space.

2.4 Bellman Equation and Strategies

Let $V_i(b)$ denote the expected net present value of future cash flows to firm i in state b. Firm i's Bellman equation is

$$V_i(b) = \max_{p_i} E_r \left[\phi_{ri}(b, p_i, p_{-i}(b))p_i + \beta \sum_{j=0}^{N} \phi_{rj}(b, p_i, p_{-i}(b))\overline{V}_{ij}(b) \right], \tag{1}$$

where $p_{-i}(b)$ are the prices charged by firm i's rivals in equilibrium (given the installed bases), the (constant) marginal cost of production is normalized to zero, $\beta \in [0, 1)$ is the discount factor, and $\overline{V}_{ij}(b)$ is the continuation value to firm i given that firm j wins the current consumer.

Differentiating the right-hand side of equation (1) with respect to p_i and using the properties of logit demand yields the first-order condition

$$E_r \left[-\phi_{ri}(1 - \phi_{ri})(p_i + \beta\overline{V}_{ii}) + \phi_{ri} + \beta\phi_{ri} \sum_{j \neq i} \phi_{rj}\overline{V}_{ij} \right] = 0. \tag{2}$$

The pricing strategies $p(b)$ are the solution to the system of first-order conditions.

2.5 Equilibrium

I focus attention on symmetric Markov perfect equilibria (MPE), where symmetry means agents with identical states are required to behave identically. I restrict attention to pure strategies, which follows the majority of the literature on numerically solving dynamic stochastic games (Pakes and McGuire (1994), Pakes and McGuire (2001)). As is true with many other dynamic models, there may exist multiple MPE. I therefore take a widely used selection rule in the dynamic games literature by computing the limit of a finite-horizon game as the horizon grows to infinity (for details see Chen, Doraszelski, and Harrington (2009)). With this equilibrium selection rule in place, the iterative algorithm always converged and resulted in a unique MPE.

2.6 Parameterization

The key parameters of the model are the strength of network effect θ, the switching cost k, the rate of depreciation δ, and the quality of the outside good v_0. I start with $v_0 = -\infty$, so that the market size is fixed, then compare results with when v_0 is not too low so that market size is endogenously determined. The lower bound for δ is zero and corresponds to the unrealistic case in which installed bases never depreciate. If δ is sufficiently close to one, then the industry never takes off. I consider many values for δ between 0 and 0.2, with the focus on intermediate values around 0.1. I investigate the following values for the strength of network effect and the switching cost: $\theta \in \{0, 0.25, ..., 4\}$, and $k \in \{0, 0.25, ..., 3\}$. While I extensively vary the key parameters, I hold the remaining parameters constant at $N = 2$, $M = 20$, and $\beta = \frac{1}{1.05}$, which corresponds to a yearly interest rate of 5%. I have no reason to think that the results are sensitive to these parameters.

3 Tipping Equilibrium and Sharing Equilibrium

In the model two types of equilibria emerge, Tipping and Sharing. In the former, the market tends to be dominated by a single firm, whereas in the latter, the market tends to be shared by firms that are of comparable size. Real-world examples of market tipping in industries with network effects and switching costs include the QWERTY keyboard, the VHS format in the home VCR market, Windows PC operating system, etc. Examples of market sharing include video game consoles, cell phone networks, credit card payment systems, etc.[1] Below we examine these two types of equilibria in turn.

3.1 Tipping Equilibrium

In a *Tipping* equilibrium, there is intense price competition when firms' installed bases are of comparable size, and the limiting distribution of installed bases is bimodal with a lot of mass at asymmetric states. An example of a Tipping equilibrium is shown in Figure 1. The policy function in a Tipping equilibrium features a deep trench along and around the diagonal. When the industry is sufficiently away from the diagonal, price is relatively high. This type of equilibria is also found in prior dynamic models with increasing returns, such as Doraszelski and Markovich (2007), Besanko, Doraszelski, Kryukov, and Satterthwaite (2008), and Chen, Doraszelski, and Harrington (2009).

[1] See Farrell and Klemperer (2007) and the references cited there for a large set of case studies.

The value function of a firm presented in Figure 1 shows that the larger firm enjoys a much higher value than the smaller firm. It is this substantial difference between the market leader's value and that of the market follower that drives the intense price competition in reasonably symmetric states. Each firm prices aggressively in hope of getting an installed base advantage and forcing the rival to give up. Hence the deep trench along and around the diagonal.

When the industry is sufficiently away from the diagonal, price competition is weak as reflected in the relatively high prices (the plateaus off of the diagonal). The smaller firm gives up the fight by not pricing aggressively, and accepts having a low market share. If instead it were to price aggressively and try to overtake the larger firm, it would have to price at a substantial discount for an extended period of time. The smaller firm avoids such an aggressive strategy because it is not profitable, thus ensuring that the larger firm enjoys a dominant position and high profits.

To show the evolution of the industry structure over time, Figure 1 also plots the T-period transient distributions of installed bases, which gives the frequency with which the industry state takes a particular value after T periods, starting from state $(0, 0)$ in period 0. A comparison of the transient distributions after 5, 15, 25 periods shows that over time, the industry state moves towards asymmetric outcomes, with more and more mass dispersed away from the diagonal.

Turning to the long-run industry structure, the limiting distribution in Figure 1 gives the frequency with which the state takes a particular value after many periods. The limiting distribution is bimodal, indicating that market tipping is highly likely.

A tipping equilibrium occurs when network effect is modest to strong, switching cost is not too strong, and depreciation of the installed bases is modest. The next section gives more details on the parameterizations for which a Tipping equilibrium occurs.

3.2 Sharing Equilibrium

The characteristic of a *Sharing* equilibrium is that the limiting distribution is unimodal with a lot of mass at reasonably symmetric states, indicating that market tipping is highly unlikely. Based on the shapes of the equilibrium policy functions, Sharing equilibria can be divided into four subtypes: Flat, Rising, Peaked, and Dual-trenchy.

A *Flat* equilibrium occurs in the degenerate case in which both network effect and switching cost are zero. Without those two factors, the model is static and moreover, the installed bases do not affect firms' pricing decisions. Consequently, the policy function is flat, so is the value function.

A *Rising* equilibrium is characterized by a fairly monotonic policy function in which a firm's price increases in its own base and decreases in its rival's base. Similarly, a firm's value monotonically increases in its own base and decreases in its rival's base. This equilibrium occurs when both network effect and switching cost are weak.

Below we focus attention on the other two subtypes of Sharing equilibria.

Peaked Equilibrium. A *Peaked* equilibrium is characterized by a peak in the policy function when each firm has half of the consumers in its installed base. Away from this peak, price drops rapidly for the smaller firm, and mildly for the larger firm. An example of a Peaked equilibrium is shown in Figure 2.

When each firm locks in half of the consumers, price competition is weak as reflected in the peak in the policy function. Due to switching costs, both firms have strong incentives to charge high prices to "harvest" the locked-in consumers. Off of the peak, the smaller firm drops its price substantially in order to increase expected sales and thereby reduce the installed base differential and move the industry back to the peak. The larger firm also drops its price, but that is a response to the smaller firm's aggressive pricing (as prices are strategic complements), rather than an effort to achieve market tipping. In fact, as the industry moves away from the peak, the smaller firm drops its price much more aggressively than the larger firm.

Such pricing behavior of the firms results in the value function also having a peak when each firm locks in half of the consumers. Off of the peak, the smaller firm's value drops rapidly whereas the larger firm's value drops mildly. Switching costs enable the firms to segment the market and focus on their locked-in consumers rather than their rivals'. Locked-in consumers are heavily exploited, and firms enjoy high profits. When one firm gains an installed base advantage, its value actually decreases because the balance is damaged, the smaller firm starts to price aggressively, and the larger firm has to respond by cutting its own price.

Since firms have little incentive to induce market tipping in their favor, market tipping is highly unlikely, as reflected in the unimodal transient distributions and limiting distribution presented in Figure 2.

A Peaked equilibrium occurs when network effect is not strong but switching cost is.

Dual-trenchy Equilibrium. In a *Dual-trenchy* equilibrium, there is intense price competition when firms' installed bases are modestly different. An example of a Dual-trenchy equilibrium is shown in Figure 3. The policy function features two trenches that divide the state space into three basins of attractions: a central basin and two peripheral basins (the resultant forces in these basins of attractions are discussed in the next section).

A Dual-trenchy equilibrium can be considered as a hybrid of a Tipping equilibrium and a Peaked equilibrium. The central basin resembles a Peaked equilibrium: prices are highest when each firm locks in half of the consumers. Off of the peak, the smaller firm's price drops rapidly whereas the larger firm's price drops mildly. On the other hand, the peripheral basins resemble a Tipping equilibrium: prices are relatively high, reflecting that price competition is weak. The smaller firm, seeing little hope of catching up with the larger firm, gives up the fight by not pricing aggressively, thereby ensuring the larger firm a persistent position of dominance.

Correspondingly, in the central basin, the value function peaks when each firm locks in half of the consumers. In the peripheral basins, the larger firm enjoys a much higher value than the smaller firm. The transient distributions and the limiting distribution are unimodal with a lot of mass at reasonably symmetric states, indicating that tipping is unlikely.

A Dual-trenchy equilibrium is reminiscent of a Compatibility equilibrium in network industries reported in Chen, Doraszelski, and Harrington (2009), which also features two trenches in the policy function and three basins of attraction in the state space. There the central basin is created by compatibility between firms' products, and here the central basin is created by switching costs.

A Dual-trenchy equilibrium occurs when both network effect and switching cost are strong.

4 Switching Costs and Market Tipping

In this section we investigate how switching costs affect the tendency towards market tipping in network industries.

Fat-cat Effect and Network-solidifying Effect. The literature on switching costs without network effects find that markets with switching costs tend to be stable: switching costs make larger firms charge higher prices than smaller firms, and therefore asymmetries in market shares are dampened over time (Beggs and Klemperer (1992), Chen and Rosenthal (1996), Taylor (2003)). This is referred to as the *fat-cat* effect, with the larger firms being less aggressive “fat cats”.[2]

In markets with network effects, switching costs have another effect on the tendency towards market tipping. First note that a basic property of network effects is that they can tip the market to one firm as soon as it has an installed base advantage. However, for a firm to price aggressively and give up current profit, the prospect of future dominance by investing in its installed base must be sufficiently great, which requires that network effects are sufficiently strong and that the installed base does not depreciate too rapidly. This is where switching costs play a role: everything else being equal, stronger switching costs make consumers in the installed base less likely to switch to other products. Consequently, an installed base advantage becomes longer-lasting. We refer to this effect as the *network-solidifying effect* of switching costs. This effect intensifies price competition when firms' installed bases are of comparable size. And when an installed base differential emerges, this effect discourages the smaller firm from pricing aggressively (since it is now more difficult for it to catch up) and encourages the larger firm to build on its advantage (since the prospect of future dominance is better). As a result, the network-solidifying effect of switching costs reinforces network effects and make market tipping more likely.

The above shows that switching costs have two opposite effects on the tendency towards market tipping: the fat-cat effect makes tipping less likely, whereas the network-solidifying effect makes tipping more likely. Which of these two effects dominates? The results from the dynamic model show that when switching costs are low, the network-solidifying effect

[2] The term “fat-cat effect” is introduced by Fudenberg and Tirole (1984).

dominates and an increase in switching costs can change the market from a sharing equilibrium to a tipping equilibrium. When switching costs are high, the fat-cat effect dominates and an increase in switching costs can change the market from a tipping equilibrium to a sharing equilibrium.

As a snapshot of the parameter space, Table 1 reports the type of equilibrium for when the quality of the outside good $v_0 = -\infty$, the rate of depreciation $\delta = 0.1$, the strength of network effect $\theta \in \{1, 2, 3, 4\}$, and the switching cost $k \in \{0, 0.25, ..., 3\}$. When θ is 2, an increase of k from 0 to 0.25 changes the market from a Rising equilibrium to a Tipping equilibrium, whereas an increase of k from 1.5 to 1.75 changes the market from a Tipping equilibrium to a Peaked equilibrium. Similarly, when θ is 3, an increase of k from 2.25 to 2.5 changes the market from a Tipping equilibrium to a Dual-trenchy equilibrium. This pattern persists when we vary v_0 and δ.

Prior literature on switching costs has identified two opposite effects of switching costs on prices: the *harvesting effect* (firms' incentive to charge high prices to "harvest" the locked-in consumers for greater current profits) and the *investment effect* (firms' incentive to charge low prices to "invest" in market share and hence increase future profits). The effects of switching costs on market tipping are closely related to those two effects. The fat-cat effect is a direct consequence of firms' asymmetric harvesting incentives when they have different installed bases, and the network-solidifying effect operates by making a network size advantage longer-lasting, thus strengthening firms' investment incentives when they have comparable installed bases.

A policy implication of the above analysis is that a regulator needs to carefully examine the interaction of switching costs and network effects when designing policies on network industries. In particular, in markets with modest network effects, policy intervention to remove switching costs may substantially reduce the likelihood of market tipping by taking away the network-solidifying effect of switching costs.

Resultant Forces. We next take a closer look at the industry dynamics by examining the resultant forces, which report the expected movement of the state from one period to the next. Figure 4 shows the resultant forces for the parameterizations in Figures 1 to 3. In the top panel, there are strong network effects ($\theta = 3$) and modest switching costs

($k = 1$), and a Tipping equilibrium results. Once an installed base differential emerges due to randomness in demand and depreciation, the state moves away from symmetry as the larger firm builds on its advantage. The state space has two basins of attraction, each with an attractor in a highly asymmetric state. Increasing dominance resulting from network effects complemented by the network-solidifying effect of switching costs makes market tipping highly likely.

In the middle panel of Figure 4, there are modest network effects ($\theta = 1$) and strong switching costs ($k = 2$), and a Peaked equilibrium results. The dominant force here is the fat-cat effect of switching costs. There is a strong attraction towards the diagonal, because the larger firm charges high prices to exploit its locked-in consumers, thus eroding its installed base advantage. The state space has one basin of attraction, with an attractor on the diagonal, indicating that market tipping is highly unlikely.

In the bottom panel, there are strong network effects ($\theta = 3$) and strong switching costs ($k = 2$), and a Dual-trenchy equilibrium results. The two trenches in firms' policy function divide the state space into three basins of attraction. In the central basin, the fat-cat effect of switching costs prevails over the tendency of increasing dominance and hence the attractor is located on the diagonal, as in a Peaked equilibrium. In each of the peripheral basins, the increasing dominance prevails and hence the attractor is located in a highly asymmetric state, as in a Tipping equilibrium. As shown in the policy function in Figure 3, when the state moves away from the diagonal, the smaller firm drops its price significantly, with the intent to increase expected sales and thereby reduce the installed base differential. Such aggressive pricing by the smaller firm makes the resultant forces in the central basin point to a symmetric state on the diagonal. When the state approaches the interior border of the central basin, the smaller firm drops its price even more in order to keep the state from moving out of the central basin. However, if the state does cross the border and enters a peripheral basin, the smaller firm gives up the fight and increases its price, ensuring the larger firm a position of dominance. Consequently, resultant forces in the peripheral basins point to highly asymmetric states. Thus the resultant forces of a Dual-trenchy equilibrium nicely show the tension between the forces of increasing dominance (network effects along with the network-solidifying effect of switching costs) that drive the market towards tipping, and the fat-cat effect of switching costs that keeps the market from tipping.

If the industry starts from a reasonably symmetric state, then the outcomes of a Peaked equilibrium and a Dual-trenchy equilibrium are similar. In both cases, the long-run modal state is symmetric, and market tipping is highly unlikely. However, the industry may start from an asymmetric state, for example because the dominant position of a firm in the current-generation market is rolled forward into the next-generation market.[3] In that case, the outcomes may be different between those two types of equilibria. In a Peaked equilibrium, because there is global convergence towards a symmetric state, the long-run industry structure is likely to be reasonably symmetric even though the initial state is not. In a Dual-trenchy equilibrium, the long-run industry structure may be highly asymmetric if the industry is "trapped" in a peripheral basin of attraction.

Probability of Switching. Underlying the resultant forces is the switching of consumers from one network to the other. Figure 5 presents the probability of a type 1 consumer switching to firm 2, for the parameterizations in Figures 1 to 3. The top panel is for a Tipping equilibrium. It shows that the smaller firm generally loses consumers to the larger firm, hence the increasing dominance in the industry. The middle panel is for a Peaked equilibrium. It shows that the larger firm generally loses consumers to the smaller firm, which is the source of the attraction towards the diagonal in the state space. The bottom panel is for a Dual-trenchy equilibrium. In the central basin, the larger firm tends to lose consumers to the smaller firm, as in the Peaked equilibrium, whereas in the peripheral basins, the smaller firm tends to lose consumers to the larger firm, as in the Tipping equilibrium. As a result, whether the long-run market outcome is symmetric or not depends on the initial state.

Long-run Herfindahl Index. Figures 6 and 7 provide a broader set of confirming results, by reporting the expected long-run Herfindahl index (based on sales) using the probabilities in the limiting distribution as weights. When the long-run Herfindahl index exceeds 0.5, asymmetries arise and persist. Figures 6 and 7 embody several general patterns across the parameter space. First, as discussed above, when switching costs are low, an

[3] For example, when AOL proposed to acquire Time Warner in 2000, the principle economic issue at the FCC was the ability of AOL to leverage its dominant position in text-based Instant Messaging (IM) into next-generation IM services using the cable assets that it proposed to acquire (Faulhaber (2004)).

increase in switching costs tend to change the market from a sharing equilibrium to a tipping equilibrium, and when switching costs are high, an increase in switching costs tend to change the market from a tipping equilibrium to a sharing equilibrium. Second, as network effects become stronger, the range of switching costs for which market tipping occurs is widened. Third, when network effects are not strong and the outside good is not too inferior, switching costs do not cause market tipping. For example, with $\theta = 1.5$ and when k is gradually increased from 0 to 2, a Tipping equilibrium does not occur for $v_0 = -3$ but does occur when v_0 is lowered to -4. For a Tipping equilibrium to occur, the expected future return to having a dominant position in the market must be sufficiently strong. If network effects are not strong, then the quality of the outside good may determine whether it is worthwhile to fight for market dominance: if the outside good is relatively attractive, then the ability of a dominant firm to reap large profits is restrained by the competition from the outside good, making it unprofitable for firms to price aggressively in order to achieve market dominance.

5 Conclusion

This paper investigates the effects of switching costs in network industries. I find that the relationship between switching costs and the tendency towards market tipping is generally non-monotonic. When switching costs are high, the fat-cat effect dominates and an increase in switching costs can change the market from a tipping equilibrium to a sharing equilibrium. When switching costs are low, the network-solidifying effect dominates and an increase in switching costs can change the market from a sharing equilibrium to a tipping equilibrium. Policy intervention to remove switching costs in network industries may substantially reduce the likelihood of market tipping. In ongoing work, I am also investigating the price and welfare effects of switching costs in network industries.

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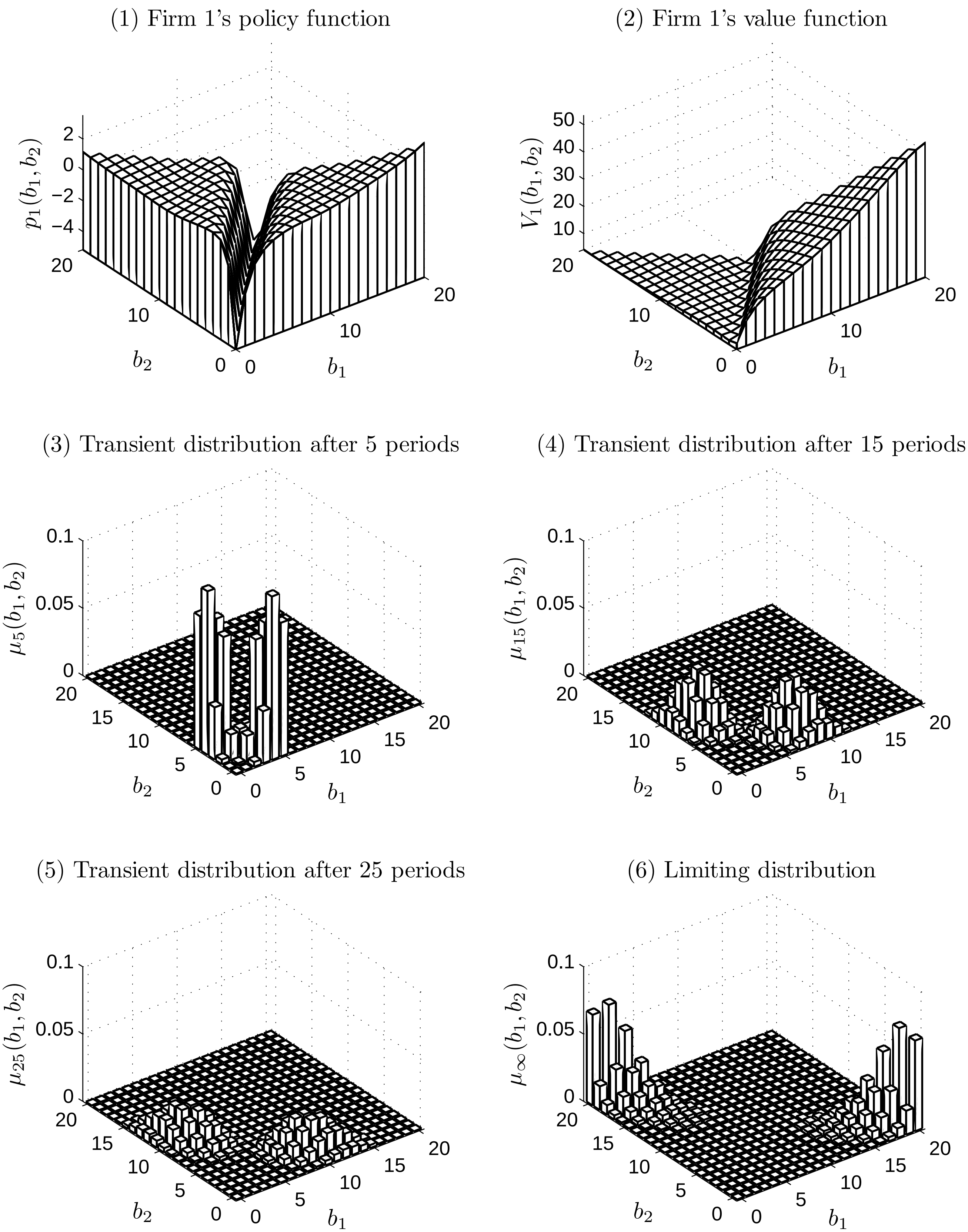

Figure 1. Tipping equilibrium: $v_0 = -\infty$, $\delta = 0.08$, $\theta = 3$, $k = 1$

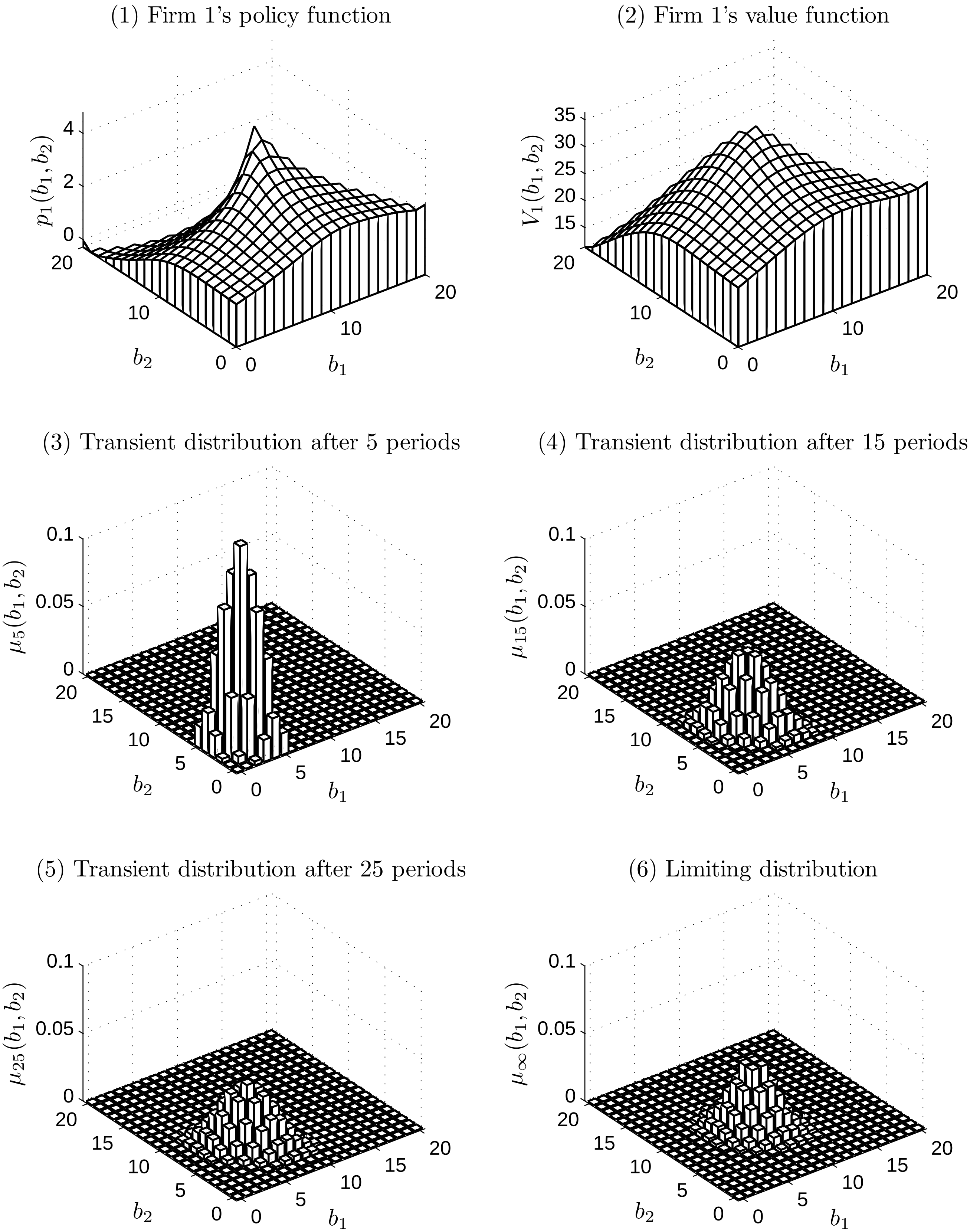

Figure 2. Peaked equilibrium: $v_0 = -\infty$, $\delta = 0.08$, $\theta = 1$, $k = 2$

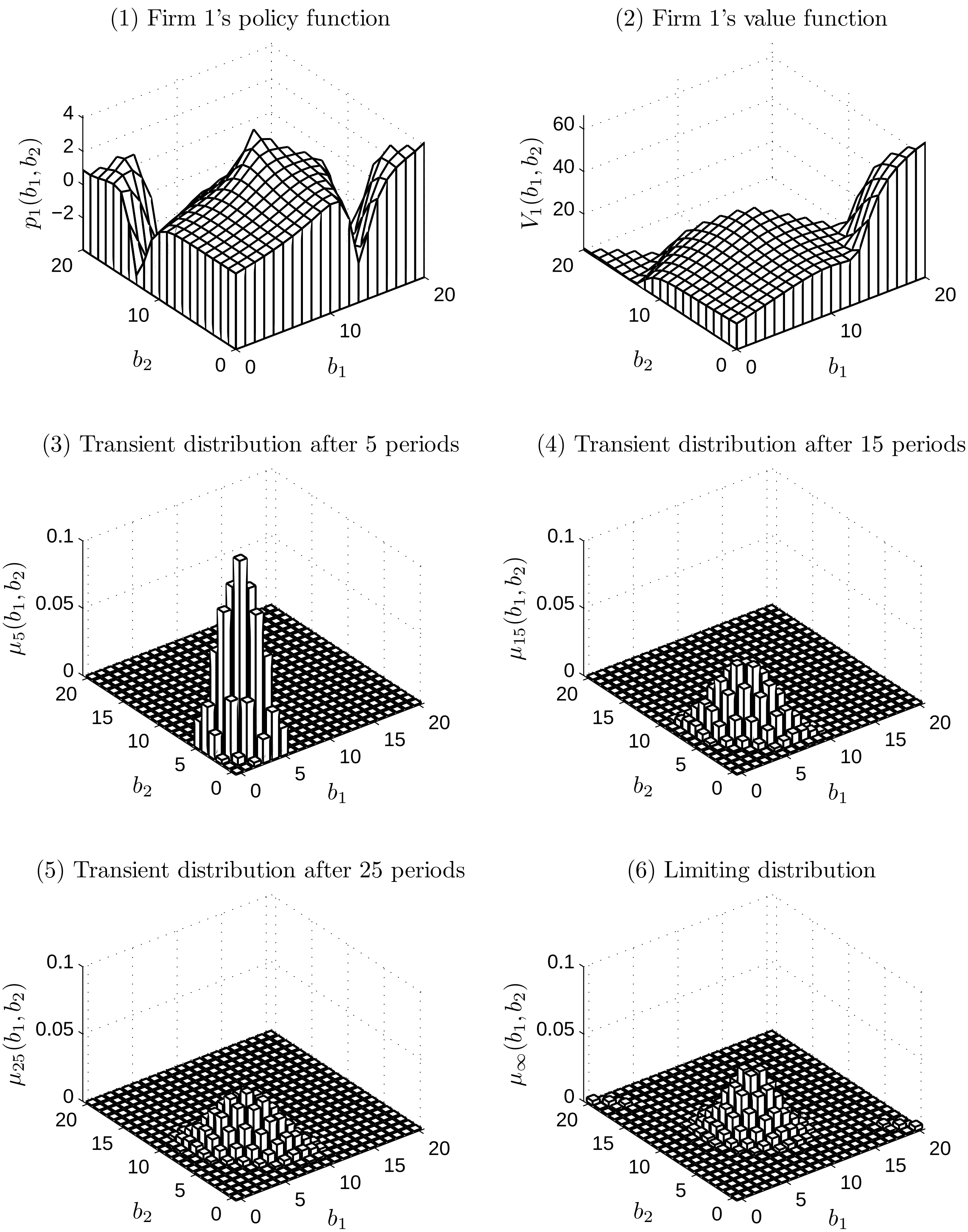

Figure 3. Dual-trenchy equilibrium: $v_0 = -\infty$, $\delta = 0.08$, $\theta = 3$, $k = 2$

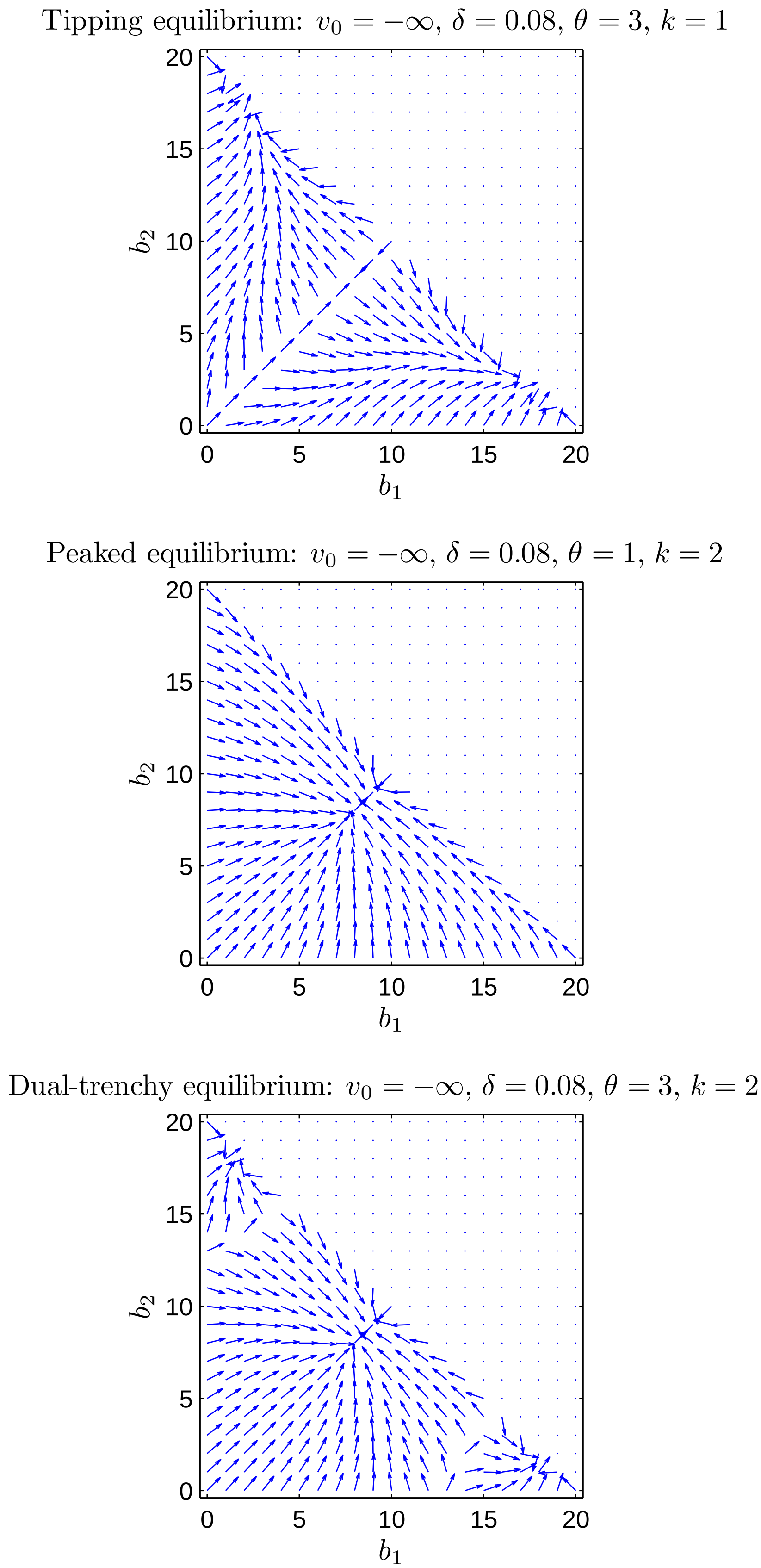

Figure 4. Resultant forces

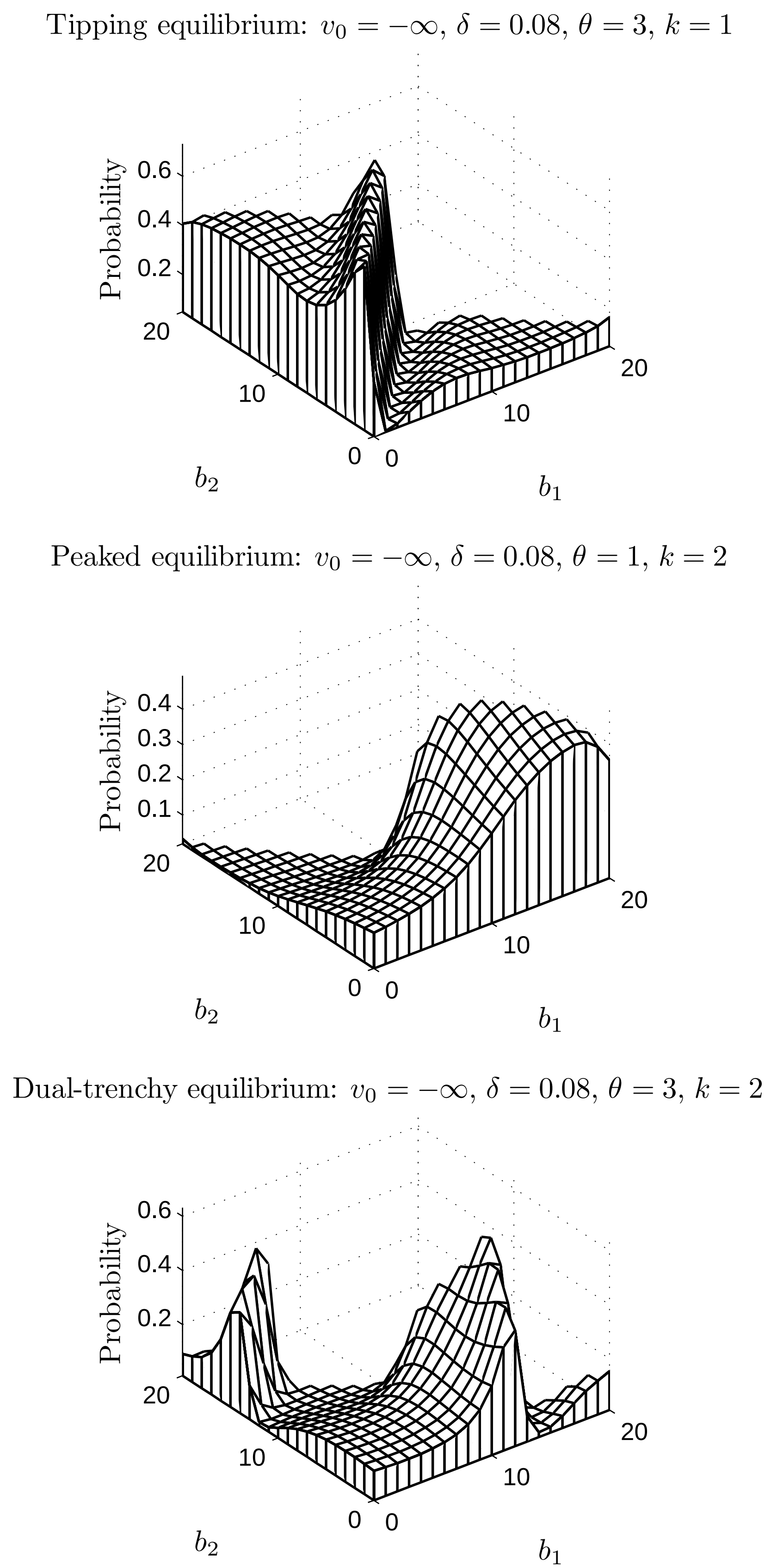

Figure 5. Probability of a type 1 consumer switching to firm 2

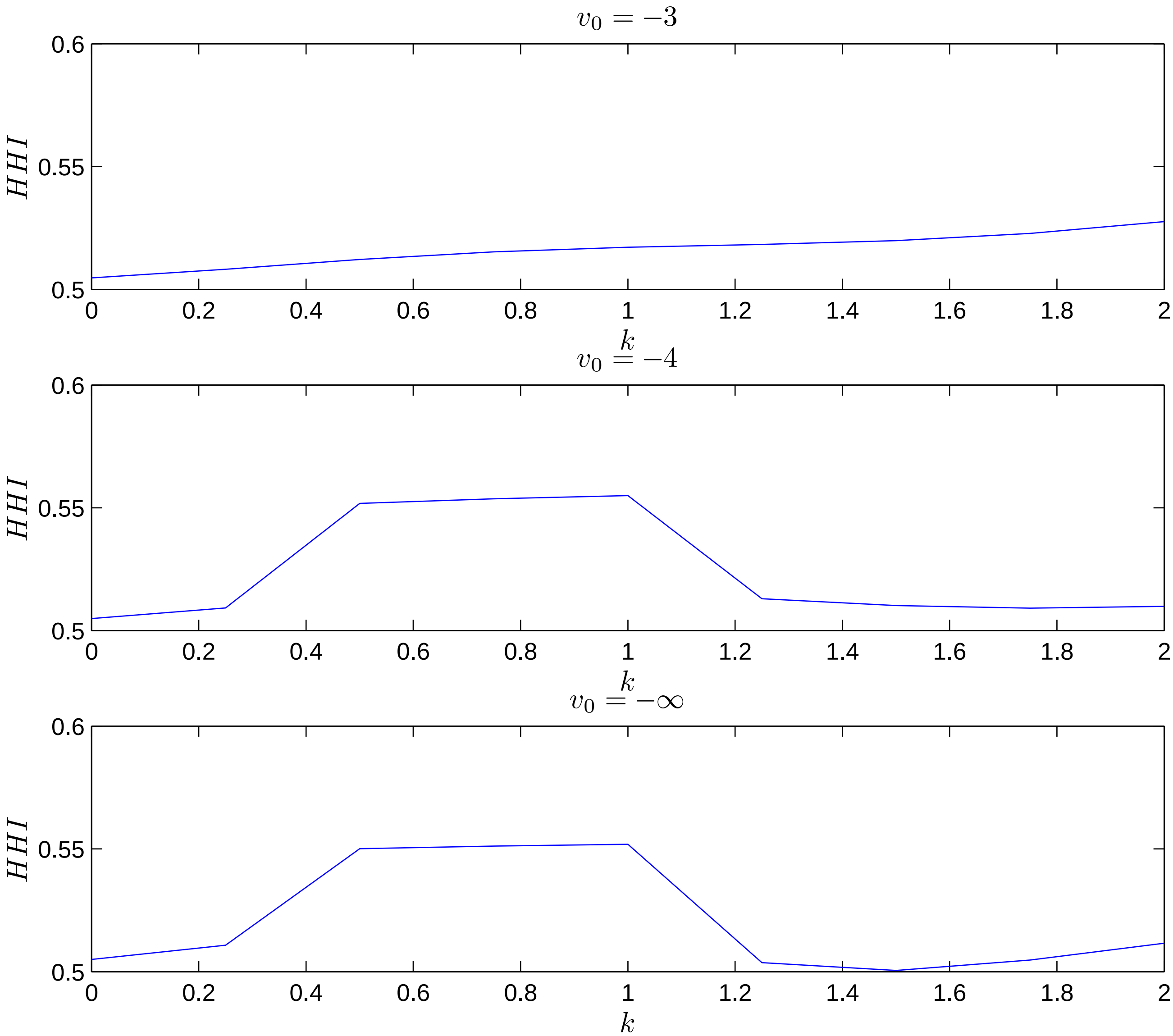

Figure 6. Long-run Herfindahl index, $\delta = 0.08$, $\theta = 1.5$

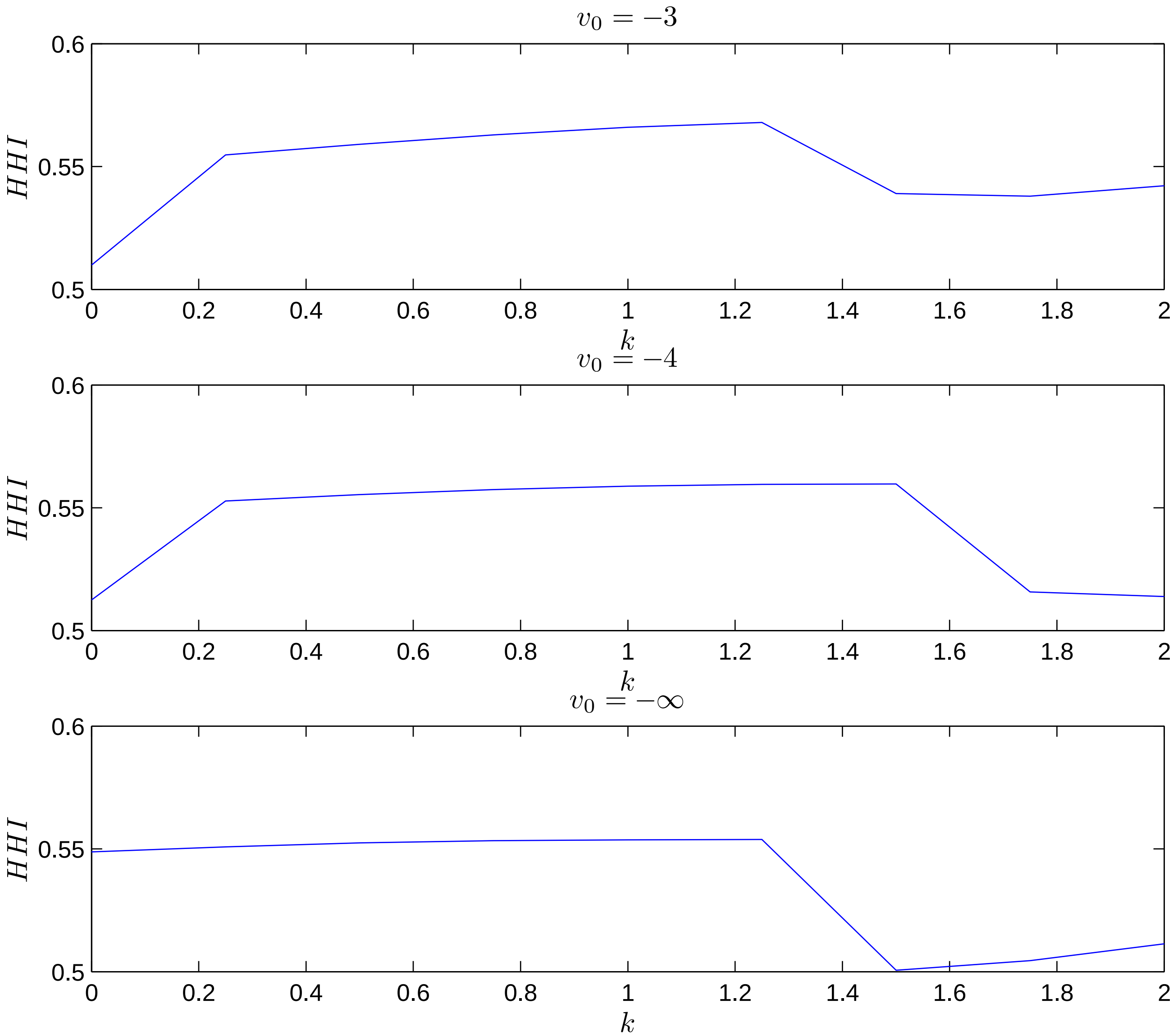

Figure 7. Long-run Herfindahl index, $\delta = 0.08$, $\theta = 1.75$

Table 1. Type of Equilibrium, v_0 = -inf., δ = 0.1

		k												
		0	0.25	0.5	0.75	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3
θ	1	R	R	R	R	R	P	P	P	P	P	P	P	P
	2	R	T	T	T	T	T	T	P	P	P	P	P	P
	3	T	T	T	T	T	T	T	T	T	T	D	D	D
	4	T	T	T	T	T	T	T	T	T	T	T	T	T

Tipping:	T
Rising:	R
Peaked:	P
Dual-trenchy:	D