

## ABSTRACT

Title of dissertation: DYNAMIC COMPETITION WITH  
CUSTOMER RECOGNITION  
AND SWITCHING COSTS:  
THEORY AND APPLICATION

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This dissertation aims to contribute to our understanding of dynamic interaction in duopoly markets. Chapter 1 motivates the study and offers a brief overview of the results.

In Chapter 2 I study the dynamic equilibrium of a market characterized by repeat purchases. Such markets exhibit two common features: customer recognition, which allows firms to price discriminate on the basis of purchase history, and consumer switching costs. Both features have implications for the competitiveness of the market and consumer welfare but are rarely studied together. I employ a dynamic framework to model a market with customer recognition and switching costs. In contrast to earlier studies of dynamic competition with switching costs, these costs are explicitly incorporated in the demand functions. Two sets of market equilibria are characterized depending on the size of the switching cost. For all values of the switching cost, customer recognition gives rise to a ‘bargain-then-ripoff’ pattern in

prices and switching costs amplify the loyalty price premium. When switching costs are low, there is incomplete customer lock-in in steady state, firm profits increase in the magnitude of the switching cost and introductory offers do not fall below cost. When switching costs are high, there is complete customer lock-in in steady state, firm profits are independent of switching costs and introductory prices may fall below cost. Under incomplete lock-in and bilateral poaching, switching costs do not affect the speed of convergence to steady state; under complete customer lock-in and no poaching from either firm, convergence to steady state occurs in just one period. The model also suggests that imperfect customer recognition leads to lower profits relative to both uniform pricing and perfect customer recognition.

In Chapter 3 I use the market framework developed in Chapter 2 to examine the perception that imperfect competition hinders information sharing among rivals in games of random matching. In contrast to previous studies of information sharing, I propose a new channel through which competition may deter information sharing. This approach reveals a key role for firm liquidity by showing that information sharing among rivals is more likely to arise in markets populated by more liquid firms. Employing a dynamic duopoly framework, in which competition intensity varies with the degree of product differentiation, consumer switching costs and consumer patience, I show that more intense market competition can weaken the disincentives associated with disclosing information to a rival. I test the model's predictions using firm-level data on the information-sharing practices of agricultural traders in Madagascar. As predicted by the model, traders operating in liquid mar-

kets are shown to be more likely to share information about delinquent customers. This result is robust to the use of two alternative measures of liquidity, of which one is credibly exogenous, and two alternative ways of defining market liquidity. Furthermore, traders who report more intense competition in their market are found to be significantly more likely to share information.

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AND SWITCHING COSTS: THEORY AND APPLICATION

by

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## Dedication

To my family for their unconditional support.

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I owe my gratitude to all the people who have made this thesis possible and because of whom my graduate experience has been one that I will cherish forever.

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# Chapter 1

## Introduction

### 1.1 Outline of Thesis

Economic agents rarely make choices independently of the choices made by others. Instead, strategic interaction underlies much of economic activity and studying the manifestations and outcomes of strategic interaction has opened up a vast area of research in Industrial Organization Theory and Applied Microeconomics. Strategic considerations may take many forms. Agents may condition their optimal strategies on the strategies of other agents, on the current state of the economic setting, or on their knowledge about the preceding two factors. At the same time, agents' own actions today may affect the state of the economic environment tomorrow and influence the information sets and future strategies of their counterparts. The heterogeneity of agents' characteristics and how these characteristics affect payoffs imposes ever more stringent requirements on the information that agents must have about the characteristics of their strategic partners. In this dissertation I ex-

plore two aspects of strategic interaction among rival firms – the determination of optimal price strategies in a dynamic duopoly market, and the decision to exchange information about the past conduct of previous contractual partners.

This dissertation consists of three chapters. Chapter 1 provides the introduction and motivation of the research. In Chapter 2, I present a model of dynamic competition with customer recognition and consumer switching costs and study its equilibrium properties. Customer recognition occurs when firms are able to distinguish between new and repeat customers and can offer them different prices. I extend an earlier model of customer recognition, originally formulated by Villas-Boas (1999), and introduce consumer switching costs in the market. Consumer switching costs arise when customers incur transaction or learning costs as a result of buying from a different producer. In contrast to past studies of dynamic competition with switching costs, I am able to incorporate these costs explicitly in the demand functions and derive two sets of market equilibria depending on the size of the switching cost. I derive closed-form solutions for the equilibrium prices, which enables a comparative statics analysis. Previous studies of dynamic competition with switching costs have limited attention to the presence of high switching costs that induce customer lock-in. I do not impose this limitation in my model. For all values of the switching cost, customer recognition gives rise to a ‘bargain-then-ripoff’ pattern in prices, and switching costs amplify the loyalty price premium. When switching costs are low, there is incomplete customer lock-in in steady state, firm profits increase in the magnitude of the switching cost and introductory offers do not fall below cost. When switching costs are high, there is complete customer lock-in, firm profits are

independent of switching costs and introductory prices may fall below cost. Under incomplete lock-in switching costs do not affect the speed of convergence to steady state; under complete customer lock-in, convergence to steady state occurs in just one period. The model also suggests that imperfect customer recognition leads to lower profits relative to both uniform pricing and perfect customer recognition.

In Chapter 3, I apply the model developed in Chapter 2 in the context of firm behavior in developing countries. In developing countries, firms often cannot rely on formal institutions to enforce contracts. An alternative solution is to rely on information flows about the past performance record, or ‘reputation’, of potential partners, in order to identify reliable contacts and discourage contract breach. However, when firms deal with a specific partner for the first time, information about that partner’s contract performance is not readily observable. In a seminal paper, Kandori (1992) establishes that reputation mechanisms can limit opportunism in bilateral relationships if agents have at least some information that summarizes the past performance of their new partner. In a real-world setting, firms are often exposed to the risk of contract breach from customers and suppliers and the most likely source of information about the reputation of these parties are other firms in the market. However, it is commonly perceived that firms will not exchange valuable information with their market rivals. The goal of this essay is to formally examine this perception and identify other key factors that may affect firms’ incentives to share information with rivals. My main finding is that firm liquidity facilitates information sharing among rivals. When firms experience breach of contract, their cash flows and inventory stock may be disrupted and their ability to compete will

depend on how costly it is to raise additional capital. Liquid firms will incur low costs of capital while liquidity constrained firms will face higher such costs. Firms realize that if they have liquid rivals, they cannot profit from the rival's experience of contract breach because a liquid rival faces low cost of funds. Hence, a firm facing a liquid rival will have a weaker incentive of exposing this rival to a higher probability of contract breach by not sharing information. Therefore, information sharing will be more likely to arise in markets populated by more liquid firms relative to markets populated by liquidity-constrained firms. Furthermore, I show that more intense market competition can lower the cost of disclosing information to a rival. I test the model's predictions using firm-level data on the information sharing practices of agricultural traders in Madagascar and find support for the proposed hypothesis that liquidity has a positive effect on traders' propensity to share information. In addition, traders who report more intense competition in their market are found to be significantly more likely to share information.

## **1.2 Introduction and Motivation of Chapter 2:**

Chapter 2 builds a model of dynamic competition with imperfect customer recognition and switching costs. Customer recognition and switching costs are commonly present in markets where firms can distinguish their repeat customers and can practice price discrimination on the basis of purchase history. However, the literature has largely reviewed the impact of these two features separately and there are no dynamic models that integrate both. In this essay, we show that the joint

presence of imperfect customer recognition and switching costs brings qualitative changes in the market equilibrium when compared to models that exhibit only one of these features. Furthermore, we allow for the presence of overlapping generations of consumers, which generates three groups of customers based on their purchase history – new, unattached consumers; customers who switch away from their original supplier; and customers who stay with their original suppliers. We first present a model of ‘imperfect’ customer recognition – firms can distinguish between new and repeat customers but they do not know if a new customer is a switcher or a newcomer to the market. Then, we dispose of this latter assumption and show that firms’ ability target all three groups of customers with a different price increases firm profits. By comparing our results of the competitive outcome under imperfect customer recognition to comparable studies of uniform pricing, it is also seen that firms would be better off in a market where repeat customers cannot be distinguished from new customers. This result holds for markets with high switching costs that induce complete customer lock-in and is due to the fact that under customer recognition firms compete away the gains from selling to loyal customers at a premium in the competition for market share.<sup>1</sup>

There are few models that consider the interaction of customer recognition and consumer switching costs, namely Chen (1997), Gehrig and Stenbacka (2002), and Taylor (2003). Chen (1997) and Taylor (2003) consider markets that consist of a single generation of consumers. In the initial period of the game consumers

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<sup>1</sup>The comparison cannot be extended to equilibria with switching because there is no benchmark model of uniform pricing, i.e. a dynamic model with product differentiation, switching costs and uniform pricing that also allows switching in equilibrium.



enter the market and firms compete for market share. In the subsequent period(s), there are no new incoming generations. Firms recognize their previous customers and engage in price discrimination by offering discounts to the rival's customers (a practice commonly referred to as 'poaching'). A key aspect of this analysis is that after the initial period there are only two types of customers, – loyal customers, who stay with their original supplier, and switchers, who change suppliers. Firms can target each group with a different, optimally chosen price. Therefore, models that consider competition for a single generation of consumers artificially induce a separation between unattached consumers and switchers by assuming that all consumers enter the market in some initial period while switching occurs in the subsequent periods when there are no new cohorts. I extend this line of research by considering the more realistic setting where in each period an old cohort of consumers exits the market and a new cohort enters – thus, each period firms face overlapping generations of consumers, – and explore the impact of firms' inability to distinguish between newcomers and switchers on the market equilibrium.

A setting with overlapping generations of customers is particularly relevant for markets with high rates of new consumer entry and somewhat low switching costs that make the change of suppliers feasible. Examples include markets for the provision of high-speed data (e.g., cable, internet and cell phone services), credit card services, movie rentals, and others.<sup>2</sup> In many of these markets firms are unable to distinguish between newcomers and switchers because it is easier to obtain infor-

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<sup>2</sup>For example, as consumers choose to upgrade from dial-up to broad-band internet, the two main internet service providers, Comcast and Verizon, face substantial demand from new, unattached consumers. At the same time, the two firms actively engage in poaching each other's existing customers.

mation on the purchase history of one's own customers (e.g., by enticing customers to enroll in loyalty programs offering discounts or to set up membership accounts that reduce transaction costs), rather than on the purchase history of the rival's customers. For this reason, the main focus of this study is on the impact of *imperfect* customer recognition. This analysis is presented in Sections 2.2 through 2.3.1. For the rest of the paper, the term 'customer recognition' will be used to refer to imperfect customer recognition unless specified otherwise.

Since newcomers and switchers have different price elasticities, firms would be willing to set different prices to each group if they could separate the two markets. Such practice would give rise to *perfect* customer recognition. Pazcal and Soberman (2007) report that Air Canada used to give promotional offers exclusively to Aeroplan members. In 2006 Blockbuster ran a promotional campaign that gave free movie rentals to Netflix subscribers.<sup>3</sup> In Section 2.4 I construct a simple two-period model that is sufficient to capture the market outcome under perfect customer recognition. I show that perfect customer recognition generates higher profits and for sufficiently low switching costs reverses the loyalty price premiums that loyal customers pay under imperfect customer recognition. For low switching costs, switchers would be offered the lowest price and newcomers – the highest. This occurs because lower switching costs erode the profits from market share and relax competition for new customers. When switching costs are sufficiently high, introductory offers emerge as in the case with imperfect customer recognition. This

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<sup>3</sup>Netflix subscribers were required to prove membership by bringing in their Netflix envelope flaps.

result explains the practice of inducing the rival's customers to reveal their purchase history and offering deeper discounts to switchers.

A systematic analysis of the impact of customer recognition in a market with overlapping generations of consumers is necessary because firms face two conflicting incentives in setting their price to new customers – on one hand, they want to maximize profits from switchers, and, on the other, they want to invest in market share. We do not have clear intuition as to which incentive will exercise stronger downward pressure on the price to new customers and how this will affect the competition of market share. Villas-Boas (1999) shows that customer recognition intensifies competition to the point that price to new customers may fall down to marginal cost. It is unclear how switching costs will affect this finding. High switching costs may weaken the incentive to poach and thereby raise the price to new customers, but they may also increase the return to market share, so firms will bid that price down. The literature on exogenous switching costs has shown that typically switching costs give rise to loyalty premiums, i.e. loyal customers pay higher prices than new customers, and in markets for homogeneous goods rents from exploiting consumers due to switching costs are dissipated in the competition for market share. In our model we will demonstrate that the level of the loyalty premium and the degree to which rents from switching costs are competed away depend on the size of the switching cost. If switching costs are sufficiently high to cause complete customer lock-in, then the incentive to poach disappears and firms would set the price to new customers with the only goal of capturing market share. As a result, any gains associated with the presence of switching costs will be competed away. In contrast, when switching

costs are low and firms can poach the rival's customers, the loyalty price premium and firm profits will be increasing in the size of the switching cost.

So far, the only model that incorporates switching costs and customer recognition while considering the impact of overlapping generations of consumers appears in Gehrig and Stenbacka (2002). The authors employ a two-period model to analyze the stationary equilibrium of the dynamic game between two infinitely-lived firms. However, by limiting attention to the case where switching costs are sufficiently high to prevent switching, they do not allow for the presence of switchers, which is what makes the overlapping generations setting interesting. Their two main findings are that introductory offers to new customers only emerge for a strictly positive level of the switching cost and the combination of price discrimination by purchase history and the presence of high switching costs reduces firm profits relative to a setting with zero switching costs. In the present study, which incorporates similar features but rests on an infinite-horizon dynamic model and investigates the market equilibrium for all levels of the switching costs, I find that firm profits increase in the size of the switching costs. Furthermore, Villas-Boas (1999) and this study show that under imperfect customer recognition introductory offers would appear even if switching costs were zero. The disparity between the results in Gehrig and Stenbacka (2002) and the model here as well as the original framework by Villas-Boas suggests that a dynamic model is indeed necessary to capture the complex processes in a market characterized by overlapping generations of consumers and customer recognition.

The present model is also closely related to the broader strand of literature on imperfect competition with customer recognition. Customer recognition gives rise

to a non-traditional form of price discrimination commonly referred to as behavior-based price discrimination.<sup>4</sup> Holmes (1989) shows that price discrimination in an imperfectly competitive market does not necessarily increase firm profits. Corts (1998) further demonstrates that in oligopolies with differentiated goods best response asymmetry does not allow us to make a priori predictions about the impact of price discrimination on firm profits and social welfare. Chen (1997) and Fudenberg and Tirole (2000) develop two-period models to examine the impact of behavior-based price discrimination on market outcomes. Chen looks at a homogeneous-good duopoly and shows that profits are lower when firms engage in price discrimination. He further shows that the price to loyal customers and the discount to switchers are increasing in the cost of switching. In his model, the presence of switching costs is the only cause of introductory offers to switchers. Fudenberg and Tirole (2000) shift the focus towards markets with product differentiation but no switching costs and examine the market equilibrium under short-term and long-term contracts. With fixed consumer preferences and short-term contracts, poaching gives rise to discounts for loyal customers. This result is in contrast with the switching costs literature where discounts are geared towards new customers. Villas-Boas (1999) extends the analysis of Fudenberg and Tirole to an infinite-horizon model and shows that, even in the absence of switching costs, infinitely-lived firms will optimally offer discounts to new customers. This result will persist in our model as well and is due to the fact that there is product differentiation – customers’ choice of supplier in their first

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<sup>4</sup>For an excellent survey of behavior-based price discrimination models see Fudenberg and Villas-Boas (2005).

purchase reveals information about their relative preferences with respect to each firm's product. Villas-Boas shows that customer recognition intensifies competition for new customers and drives both the price to new customers and the price to loyal customers down.<sup>5</sup> All three of these studies – Chen (1997), Fudenberg and Tirole (2000), and Villas-Boas (1999) – conclude that firms are worse off when they price discriminate on purchase history as opposed to uniform pricing. With respect to imperfect price discrimination, this result is preserved in the present study as well.<sup>6</sup>

The literature on switching costs examines the impact of these costs in the light of two distinct settings: one, based on homogeneous goods and heterogeneous switching costs, and another, based on heterogeneous goods and homogeneous costs.<sup>7</sup> The subsequent analyses of the impact of switching costs on market competitiveness have mostly relied on two-period models because of their tractability which allows for the examination of a wide variety of features and problems.<sup>8</sup> Nevertheless, there are a few dynamic models that look at the impact of switching costs on incumbency advantages, the incentives for collusion, and the competitiveness of the market. All but one of these dynamic models are based on uniform pricing strategies. The only exception is Taylor (2003) who allows for customer recognition but his framework does not allow for overlapping generations of consumers and assumes that firms have a finite horizon. All other dynamic models feature overlapping generations of

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<sup>5</sup>In Villas-Boas' model the price to loyal customers is set sequentially after the introductory prices are announced and its optimal level is increasing in the introductory price of the rival.

<sup>6</sup>The lack of closed-form solutions for the uniform-pricing models preclude a comparison between profitability under uniform pricing and perfect customer recognition.

<sup>7</sup>The lack of pure-strategy equilibrium constrains the analysis of homogeneous goods and homogeneous switching costs.

<sup>8</sup>For a thorough review of the literature on switching costs see Farrell and Klemperer (2007).

consumers and uniform pricing strategies. Farrell and Shapiro (1988) and Padilla (1995) examine a market with homogeneous products. Farrell and Shapiro (1988) first recognize the importance of having overlapping generations of consumers on firms' price strategies. They make the unusual assumption that firms choose a price leader in the dynamic game and show that switching costs soften competition. Padilla (1995) disposes of this assumption, because of its direct impact on competition, and allows firms to set their prices simultaneously. His results confirm that switching costs relax competition and this effect is not due to the sequential nature of the price-setting game in Farrell and Shapiro. Our own findings are consistent with this result when we limit attention to the equilibrium with switching. On the other hand, Beggs and Klemperer (1992) and To (1996) analyze a dynamic market with product differentiation and switching costs, which successfully prevent consumers from changing suppliers. The former assume that consumers have an infinite horizon as well and reaffirm the results from homogeneous markets that switching costs lead to higher prices and profits. To (1996) modifies the model in Beggs and Klemperer by assuming that consumers have a finite horizon and, specifically, enter the market for two periods only. The only qualitative difference between his results and those in Beggs and Klemperer is that in To's model convergence to steady state is non-monotonic. In both models convergence to steady state takes a sufficiently high number of periods and may be infinitely slow if firms are infinitely patient.

We present a model that features customer recognition, switching costs and overlapping generations of consumers. Two sets of market equilibria are character-

ized depending on the size of the switching cost. For all values of the switching cost, customer recognition gives rise to a ‘bargain-then-ripoff’ pattern in prices and switching costs amplify the loyalty price premium. When switching costs are low, there is incomplete customer lock-in in steady state, firm profits increase in the magnitude of the switching cost and introductory offers do not fall below marginal cost. When switching costs are high, there is complete customer lock-in in steady state, firm profits are independent of switching costs and introductory prices may fall below cost. When both firms poach in equilibrium, switching costs do not affect the speed of convergence to steady state; when neither firm finds it optimal to poach, convergence to steady state occurs in just one period. Furthermore, we find that imperfect customer recognition generates lower profits relative to both uniform pricing and perfect customer recognition.

### **1.3 Introduction and Motivation of Chapter 3:**

In the absence of adequate legal protection against contract breach, firms can reduce their exposure to contractual risk in one-shot transactions by exchanging information about defectors. The goal of this chapter is to investigate whether competition discourages such exchange and under what conditions.

Information sharing is particularly important in developing and transition economies where reliance on formal means of contract enforcement is limited. On one hand, these economies may not have adequate legal framework or efficient enforcement institutions to provide protection against contract breach. On the other



hand, informal business activity, corruption and inefficiency in the legal system may discourage the use of formal contracts and rule out recourse to the court system.<sup>9</sup> The consequences of such institutional failures can be highly detrimental as firms may limit their transactions to long-standing partners, and forgo better economic opportunities with new partners (McMillan and Woodruff, 2000).

There are several theoretically and empirically established mechanisms, through which information sharing can help firms reduce their exposure to contractual risk. Information sharing can alleviate adverse selection through reputation effects: when past performance is a signal of a player's propensity to renege on a contract, firms can screen out defectors, conditional on receiving information about the agent's record (Jappelli and Pagano, 1993). Information sharing can also have a discipline effect that discourages some players from acting opportunistically because these players can foresee that information about their actions will be publicly available (Padilla and Pagano, 2000). Sharing information about players' records can also facilitate cooperation on a wide range of problems through social-norm equilibria (Kandori, 1992; Okuno-Fujiwara and Postlewaite, 1995).<sup>10</sup> Case studies of informal coalition arrangements that sustain cooperation through social norms have given rise to variations of this game (Greif, 1993; Clay, 1997) but the dissemination of information about players' past actions remains a key function of such coalitions.

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<sup>9</sup>Schneider (2002) shows that the average size of the informal sector in 21 transition countries amounts to 38% of official GDP. Safavian and Wimpey (2007) show that the probability of an enterprise preferring to use only informal credit is inversely related to the quality of the overall quality of governance in the country.

<sup>10</sup>In fact, Kandori (1992) shows that for the cooperative equilibrium to be sustained players only need information about the 'status' of their current partner, i.e. whether the partner is to be punished in the current period for past deviations. Players do not need to know the full history of the game or the status of all players.

Past studies of contract enforcement based on social norms (Landa, 1981; Greif, 1989 and 1993; Clay, 1997; Bernstein, 1992 and 2001) do not endogenize the existence of information networks. Greif (1993) presents evidence of the active correspondence among Maghribi traders in the 11c. Cairo and their partners in the Mediterranean region on the performance of their overseas agents. Greif conjectures that this extensive communication network indicated the existence of an informal traders coalition that relied on reputation mechanisms to keep agents honest. However, Greif (2006) briefly acknowledges that if coalition members were rivals in a common oligopolistic market, they would be reluctant to share information that may benefit their competitors. In numerous studies Marcel Fafchamps and co-authors have recognized that competition may be responsible for the lack of information sharing networks in some African countries (Fafchamps et al., 1994; Fafchamps, 1996 and 1997; Fafchamps and Minten, 1998). However, to date there is no formal study on the subject. This paper complements the literature on social norms by examining the conditions under which inter-firm information sharing networks in a competitive environment are viable.

So far the literature has largely addressed the issue of information sharing on agents' contract performance from the perspective of lending institutions only (Jappelli and Pagano, 1993; Padilla and Pagano, 1997 and 2000; Bouckaert and Degryse, 2001; Gehrig and Stenbacka 2006; and Brown and Zehnder, 2008). Among these studies, few have focused on the impact of ex ante imperfect market competition on the endogenous emergence of information flows.<sup>11</sup> Jappelli and Pagano (1993),

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<sup>11</sup>A notable exception is Klein (1992) who models firms' decisions to pay a fee and join a credit

Padilla and Pagano (1997), Brown and Zehnder (2008) model banks as ex ante local monopolists and examine various aspects of information sharing on competition intensity, entry decisions and borrower performance. Jappelli and Pagano (1993) first look at the trade-offs of sharing information with potential rivals. In their model banks benefit from pooling information about the borrowing histories of their local customers but also lose their monopoly power, so the threat of more intense ex post competition can deter information sharing. Brown and Zehnder (2008) present experimental evidence in support of this theoretical result. Padilla and Pagano (1997) propose that information sharing may serve as a pre-commitment device that helps reduce moral hazard on behalf of borrowers – by agreeing to share information, banks pre-commit to limit their ability to extract rents from their customers, which increases borrower effort. Bouckaert and Degryse (2001) in turn consider the incentives of a local monopolist to unilaterally reveal information about its customers' types to a potential entrant. They find that when adverse selection is severe, not revealing information can deter entry, which makes information sharing suboptimal. If entry does occur, then two-way information sharing emerges when the level of adverse selection is large, consistent with the results in Jappelli and Pagano (1993).

Padilla and Pagano (2000) investigate how the scope of the information shared affects its disciplinary effect on borrowers in the context of perfectly competitive markets.<sup>12</sup> They find that sharing default information only (also referred to as

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bureau. However, he does not consider the role of competition on firms' incentives to reveal their private information about customer performance.

<sup>12</sup>See also Verkammen (1995) and Diamond (1989) for early studies on the impact of publicly observable credit histories on borrowers' choice of projects and effort. Brown and Zehnder (2007) present experimental evidence showing that the incentive effects of information sharing are significant only in the absence of bilaterally repeated transactions between lender and borrower.

‘black’ information) rather than the full borrowing history, has a stronger discipline effect because lenders make their inferences about a player’s type on the basis of a single incident of default. In line with this result, I limit attention to the transmission of ‘black’ information only. More recently, Gehrig and Stenbacka (2006) consider the effects of information sharing on the degree of market competition. They find that information exchange has anti-competitive implications as it facilitates poaching the rival’s ‘good’ borrowers and reduces the returns on credit relationships, thus weakening the competition for new customers.

Empirical studies of formal information sharing regimes have focused on the outcomes of these regimes in credit markets and provide strong evidence in support of the effectiveness of the reputation mechanism. Public and private credit registries have become centralized repositories of information in credit markets.<sup>13</sup> The operation of credit bureaus is shown to reduce default rates (Jappelli and Pagano, 2002), increase the volume of lending (Jappelli and Pagano, 2002; Djankov, McLiesh and Shleifer, 2007) and reduce lenders’ selection costs (Kallberg and Udell, 2003). Firm-level data shows that formal information sharing mechanisms among lenders reduce firms’ cost of credit, particularly in countries with weak legal enforcement (Brown, Jappelli and Pagano, 2009) and soften firms’ credit constraints (Love and Mylenko, 2003). Experimental evidence further demonstrates that sharing default information increases borrowers’ incentives to repay loans and without such exchange the

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<sup>13</sup>See Klein (1992) for a discussion of firms’ decision to join a credit bureau when competition is not a consideration. See Jappelli and Pagano (1993) and Padilla and Pagano (2000) for a theoretical treatment of the endogenous emergence of information sharing in credit markets. Also, see Padilla and Pagano (1997) for a study of the precision of information to be shared in order to maximize borrower performance.

credit market can collapse (Brown and Zehnder, 2006). Evidence from microdata in developing countries stresses on the efficiency gains of having an operating credit bureau, especially when borrowers understand the implications of a traceable credit history (de Janvry, McIntosh and Sadoulet, 2006; Ginè, Goldberg and Yang, 2009).

The empirical evidence on the existence of informal information sharing networks in developing economies is somewhat limited and offers mixed findings. McMillan and Woodruff (2000) find that gossip within Vietnam's manufacturing community serves an essential role in disseminating information about suppliers and customers who have reneged on their contracts. In contrast, Annen (2007) surveys informal textile producers in Bolivia and finds that most traders do not disclose information about dishonest agents and even if they do, such information is limited to one's family members, rather than directed towards other traders who would benefit most from such information. Among the few studies that recognize the role of competition on the formation of information sharing networks, Fafchamps (1996) reports the following in a particularly illustrative case study of contract enforcement in Ghana:

*'There seems to be no mechanism whereby information about clients' trustworthiness is shared among firms other than direct recommendation by common acquaintances. When prompted directly, firms declare that they never bother passing information about untrustworthy customers to other firms. Sharing information would provide competitors with an undue advantage, they say. In fact, several respondents appeared to relish the idea that their competitors have to deal with the*

*same deadbeats by whom they had been burnt.*' (Fafchamps, 1996, pg. 441.)

On the other hand, Fafchamps et al. (1994) point out with surprise that several competing textile producers in Kenya deliberately exchanged information about delinquent customers. Given the mixed anecdotal evidence on the existence of information sharing networks in different markets and the lack of a formal analysis of this issue, the current study fills an important gap in understanding how competition affects firms' decisions to share information with rivals.

The theoretical investigation in this paper differs from past studies of information sharing in credit markets in two ways. First, all existing studies model the impact of competition through the feedback effect of information sharing on lenders' market power. In contrast, I propose a different channel through which competition may hinder information sharing, based on the observation that the experience of contract breach can be particularly harmful to firms that are liquidity constrained. Firms' losses associated with contract breach include not only the value of the contracted goods/services, as it is assumed in studies focusing on lenders, but also the potential loss of market share and its implications for future profitability under an infinite horizon. This wider impact of contract breach on firms' ability to compete, particularly in environments with imperfect capital markets, has not been addressed in the literature so far. Considering firms in a developing country setting where information sharing can act as a particularly important substitute for creditor protection rights further supports the thesis that credit constraints have the potential to affect firms' strategic decisions. Second, I focus on firms rather than

lending institutions. This further justifies the emphasis on liquidity and allows us to make use of survey data at the firm level and empirically examine the factors that may have contributed to the presence of information sharing networks in some markets but not in others.<sup>14</sup> Finally, all past studies use two-period models of banking competition, through which they derive banks' net benefits from engaging in information sharing while the model at hand uses a richer, dynamic framework to model market competition.

This study is also related to the broader subject of information sharing among competing firms. A well-established strand of the literature looks into firms' incentives to pool information about uncertain demand and cost parameters. In the presence of demand or cost uncertainty, firms' optimal strategies depend on the type of competition (Bertrand or Cournot) and the source of uncertainty, i.e. demand or cost conditions (Novshek and Sonnenschein, 1982; Clarke, 1983; Vives, 1984; Gal-Or, 1985 and 1986; Li, 1985; Raith, 1996).<sup>15</sup> Except for models of Bertrand competition with cost uncertainty, unilaterally revealing information about independent values, private values or common values with strategic complementarity is shown to be a dominant strategy (Vives, 2006). More recent studies focus on firms' decisions to reveal information about their customers' purchase histories in order to determine if customers view their products as substitutes or complements (Kim and

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<sup>14</sup>Previous studies that use firm-level data, e.g. Galindo and Miller (2001), Love and Mylenko (2003), Brown, Jappelli and Pagano (2009), have studied the impact of private credit bureaus and public credit registries on credit market performance but there is no empirical study, either based on country-level or firm-level data, that examines the determinants of the emergence of information-sharing institutions.

<sup>15</sup>See Vives (2006) for a review of the literature on pooling private signals of uncertain demand and cost conditions.

Choi, 2009; Liu and Serfes, 2009).

Finally, this work also fits into the literature on informal risk-sharing arrangements (Kimball, 1988; Coate and Ravallion, 1993; Fafchamps, 1995 and 2002; Besley, 1995). Information sharing arrangements reduce firms' exposure to cost shocks triggered by the experience of contract breach. Thus, engaging in costly exchange of information about defectors can be viewed as an insurance mechanism against future shocks. Furthermore, firm access to low-cost, informal credit reduces the strategic cost of information sharing and facilitates information exchange. Hence, this paper suggests complementarities between credit and risk sharing institutions.

The main finding of this study is that market liquidity facilitates information sharing by reducing the strategic cost of disclosing information to a rival. Firms expect that withholding information about cheaters will expose the remaining firms in the market to higher risk of contract breach and the firm that withheld information may be able to profit from the rival's higher exposure to risk. However, access to liquid assets makes firms less vulnerable to the disruptions caused by experiencing contract breach. As a result, firms that face liquid rivals have weaker incentives to withhold information from these rivals. Assuming that firms within a market are similar in their access to liquidity, we can formulate the hypothesis that information sharing is more likely to emerge in markets populated by more liquid firms. This hypothesis is supported by empirical evidence based on the information-sharing practices of agricultural traders in Madagascar. The model also suggests that more intense competition may encourage or discourage information sharing, depending on what market features are driving the intensity of competition. The accompany-



ing empirical analysis shows that traders who report stronger competition in their markets are also more likely to engage in information-sharing.

## Chapter 2

# Dynamic Competition with Customer Recognition and Switching Costs

### 2.1 Introduction

This paper studies the interaction of customer recognition and switching costs in a differentiated duopoly with overlapping generations of consumers. Customer recognition refers to the practice of offering different prices to new and repeat consumers. It has become a widespread market phenomenon facilitated by the advancement of information technologies over the past two decades. Previously associated predominantly with subscription markets, today this practice is feasible in a wide variety of settings as more and more consumers provide firms with unique identifiers when using non-cash methods of payment, carrying store membership

cards or shopping online.<sup>1</sup> Combined with the low cost of information storage, it is easier than ever for companies to store and retrieve information about previous customers, opening the door to price discrimination based on purchase history. This paper shows that the dynamic properties of the equilibrium path of a differentiated duopoly with overlapping generations of consumers differ substantially depending on whether customer recognition is present. At the same time, consumers in markets characterized by repeat purchases are more likely to face real or perceived costs of switching when they purchase from different providers over time. Such costs could be purely transactional, e.g. the cost of opening a new account with a different supplier, or they could be due to learning costs arising from the need to get accustomed to a new supplier or a new product.<sup>2</sup> We demonstrate that there are two qualitatively different equilibrium paths depending on the magnitude of the switching cost. Furthermore, since purchase history reveals information about a consumer's relative preferences and allows firms to extract more surplus from their repeat customers, the presence of switching costs has the potential to increase the value of customer recognition. Therefore, switching costs become especially relevant in such markets. Yet, with a few notable exceptions, the literature so far has mostly considered the role of these two features separately from each other.

The contribution of this paper can be best understood in light of the work of To (1996) and Villas-Boas (1999). A comparison between the present model and To (1996) allows us to understand the impact of customer recognition in the presence of

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<sup>1</sup>See Taylor (2003) for a discussion of customer recognition in subscription markets.

<sup>2</sup>The classification of switching costs into transaction and learning costs was first introduced by Nilssen (1992).

large switching costs. Similar to the model in To (1996), I examine a differentiated duopoly with heterogeneous switching costs and consumers with two-period life spans. In addition, the current paper does not impose restrictions on the size of the switching cost; in contrast, To (1996) assumes that switching costs are sufficiently high to prevent switching in equilibrium. For this reason, an analysis of the impact of customer recognition is limited to markets where switching costs are high enough to cause complete customer lock-in. Under complete lock-in, firms do not face demand from switchers. The main point of distinction between the two models is that in our model firms exercise customer recognition. As mentioned above, customer recognition and the presence of switching costs are likely to occur in the same markets and it is important to understand their interaction. I find that customer recognition in a market with complete lock-in allows firms to set introductory prices that exclusively target newcomers, i.e. those consumers who are in their first period in the market. As a result, the prices offered to new customers become independent of market share and convergence to steady state occurs in just one period. In contrast, To's model shows that under uniform pricing the firm with the larger market share charges a higher price (to all customers) and the market converges to steady-state non-monotonically and after a sufficiently large number of periods.<sup>3</sup> Given complete customer lock-in, steady-state per-cohort profits are lower when firms can price discriminate relative to uniform pricing. Switching costs intensify the competition for market share and firms compete away any profits associated with

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<sup>3</sup>In a model of uniform pricing and infinitely-lived consumers Beggs and Klemperer (1992) show that convergence to steady state is monotonic but may be infinitely slow.

the resulting customer lock-in. Steady-state profits are at most equal to the profit in the static Hotelling model with no switching costs and incumbency advantages in terms of profits and market share disappear within one period. Thus my results imply that under customer recognition, the presence of high switching costs does not protect the incumbency position of the dominant firm but rather encourages entry.

From a practical point of view, firms' ability to price discriminate on the basis of purchase history allows us to derive the equilibrium prices in terms of the magnitude of the switching cost and perform comparative statics. Dynamic models of uniform pricing (Beggs and Klemperer, 1992; To, 1996) do not permit the identification of the direct impact of the switching cost on prices. This is due to the fact that in these models the switching costs do not explicitly enter the demand functions but rather justify the assumption that repeat customers cannot switch. In our setting we can derive the endogenous threshold, beyond which switching costs cause complete customer lock-in. Therefore, we can characterize the equilibrium path depending on whether switching costs are below or above this threshold level.

A comparison between our model and Villas-Boas (1996) allows us to examine the effect of switching costs on prices, profits and convergence in the presence of customer recognition. Since the model in Villas-Boas (1996) does not feature switching costs, the equilibrium results are limited to the case where there is only partial customer lock-in. In our setting, partial lock-in is preserved as long as switching costs are sufficiently low. I find that the equilibrium results from Villas-Boas' model are largely preserved except for the direct effects of switching costs on prices,

on the volume of switching, and on the probability that both firms will be able to poach in equilibrium. In particular, I find that the price to new customers is weakly decreasing in the cost of switching and as long as this cost is low enough to allow switching in equilibrium, the introductory price does not fall below marginal cost. Furthermore, switching costs raise the price to repeat customers, expand the loyal customer segment for each firm, increase profits and increase the likelihood that only one firm will be able to poach for a given distribution of the market. As long as both firms poach in equilibrium, switching costs do not affect the speed of convergence to steady state.

By adding switching costs to Villas-Boas' framework, we see that the size of the switching costs matters and can lead to two distinct equilibrium paths. When switching costs are high such that there is complete lock-in in steady state, the properties of the equilibrium change substantially. Convergence to steady state occurs in just one period, the price to new customers may fall below cost, and bilateral poaching is no longer possible. In addition, under the equilibrium with complete lock-in, I can characterize the firms' equilibrium strategies for all values of the consumer discount factor while under incomplete lock-in, Villas-Boas (1999) and my own treatment of the model is subject to the restriction that consumers are sufficiently patient.<sup>4</sup>

Finally, I examine the effect of imperfect customer recognition (ICR) on profits by examining an otherwise identical market where firms can also distinguish between

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<sup>4</sup>While I derive the closed-form solutions for the coefficients that determine the optimal price policies of the two firms, the resulting expressions cannot be meaningfully analyzed unless we limit attention to a consumer discount factor close to one.

switchers and newcomers. I refer to the latter practice as perfect customer recognition (PCR), because firms can recognize all three groups of consumers - newcomers, switchers and loyal customers. Since, the inability to price discriminate between newcomers and switchers under ICR is most relevant when switching does occur, I restrict this analysis to the case where switching costs are low enough to allow incomplete customer lock-in in steady state. I find that under PCR loyal customers and switchers receive discounts relative to newcomers and a larger fraction of old consumers switch in equilibrium. Furthermore, firm profits per cohort of consumers is higher under PCR relative to ICR although this difference is decreasing in the magnitude of the switching costs.

Section 2.2 describes the model and Section 2.3 presents the equilibrium results for the case of low and high switching costs, respectively. Section 2.4 presents the comparison of imperfect versus perfect customer recognition and Section 2.5 concludes.

## 2.2 The Model

We consider a duopoly market consisting of two infinitely-lived firms, A and B, selling a nondurable good. Consumers have uniformly distributed preferences over the products of the two firms, which gives rise to ex-ante product differentiation. The degree of product differentiation is exogenously determined and fixed. Each firm produces the good at a constant marginal cost,  $c$ . Consumers enter the market for two periods only and demand one unit of the good in each period. They have

common valuation for the good given by  $v$ , which I assume to be sufficiently high to induce a purchase in each period. In each period an old cohort of consumers exits the market and a new cohort enters. I assume that all cohorts are of the same size, although the analysis can be readily extended to accommodate cohorts of different sizes. In any given period, a firm faces two overlapping generations of consumers: old consumers in their second period in the market who have established a purchase history; and newcomers, who enter the market in the current period and have not purchased from either firm yet. If old customers purchase from the same supplier in both periods I call them ‘loyal’ customers, while if they purchase from two different suppliers over their lifetime, I call them ‘switchers’. Firms recognize their own loyal customers but cannot determine if a new customer is a newcomer with no purchase history or a switcher from the rival firm.

I use Hotelling’s framework to model product differentiation. Firms are located at the opposite ends of the unit interval with firm A located at zero. Each cohort of consumers has mass normalized to one and consumers are uniformly distributed over the unit interval. For each consumer, the distance from firm A relative to firm B is a proxy for her preference towards the two firms. I assume that these preferences are time-invariant and known to the consumer ex ante.<sup>5</sup> To model preferences, suppose that customers face a linear transportation cost of  $\tau$  per unit of distance, such that if a consumer is located at distance  $x$  from firm A, she will have to incur transportation costs of  $\tau x$  if she buys from A, or  $\tau(1 - x)$  if she buys from firm B. A

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<sup>5</sup>The literature on experience goods considers settings where consumers are ex ante unaware of their preferences and the information they obtain through purchasing from one supplier creates an endogenous cost of switching. I do not consider such situations here but the reader is referred to Villas-Boas (2004) for a model of dynamic competition with experience goods.



consumer who switches suppliers in her second period also incurs a switching cost,  $s$ , which is assumed to be time-invariant, uniform across consumers and common knowledge.<sup>6</sup> Firms compete for customers by offering an *introductory* price and a *regular* price. All new customers, which could be either newcomers or switchers, are offered an introductory price,  $p_{nt}^i$ , while loyal customers are offered a regular price,  $p_{ot}^i$ . We assume that firms simultaneously announce their introductory prices at the beginning of each period. However, each firm sets its regular price only after observing the introductory price of the rival. This assumption guarantees the existence of a pure-strategy equilibrium in periods when the distribution of market share is sufficiently unequal.<sup>7</sup> It is well known that sequentially set prices are higher than the Bertrand price. However, for the purposes of our analysis an upward bias in the regular price will not affect the results in a qualitative way.

Since my setup is based on Villas-Boas (1999), I adopt the same notation, whenever possible, to facilitate comparison of the results. Let  $i, j = \{A, B\}$ . Then, let  $q_{ii,t}$  indicate demand from firm  $i$ 's loyal customers in period  $t$ ,  $q_{ij,t}$  – demand from old customers who switch from  $i$  to  $j$  in period  $t$ , and  $q_{1i,t}$  – demand from newcomers who purchase from  $i$  in their first period in the market. To simplify some of the notation that follows, without loss of generality, I normalize marginal costs to zero for both firms. In Section 2.2 I will present the equilibrium results when marginal costs are constant, symmetric and equal to  $c \geq 0$ .

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<sup>6</sup>Since customers can switch at most once, there is no need to distinguish whether switching costs arise strictly from learning costs (which are incurred only once with each supplier) or from transaction costs (which are incurred every time a buyer switches suppliers).

<sup>7</sup>This is a common assumption in models of customer recognition where customers are heterogeneous in some characteristic (Villas-Boas, 1999; Marquez, 2002).

To set up the firms' problem, we first characterize the demand functions for each of the three groups of customers: newcomers, switchers and loyal customers. I then discuss the recursive nature of the problem and set up the firms' value functions.

### 2.2.1 Demand from Newcomers

To derive each firm's demand from newcomers, we first determine the location of the marginal consumer among newcomers in the market. This location also determines the distribution of the market in the current period and the market shares that firms will inherit in the following period. We indicate the location of the marginal consumer among newcomers at time  $t$  as  $x_{t+1}$ , where  $x_{t+1}$  will also be used to describe firm A's market share in period  $t + 1$ .

Indicate the consumer discount factor as  $\delta_c$  where  $\delta_c \in (0, 1]$ . Assuming that consumers have perfect foresight, a newcomer located at  $x$  will purchase from firm A in her first period in the market if this purchase yields a weakly higher surplus over the consumer's two-period life span in the market than the one realized when purchasing from firm B:

$$\begin{aligned} v - p_{nt}^A - \tau x + \delta_c \max(v - p_{ot+1}^A - \tau x, v - p_{nt+1}^B - s - \tau(1 - x)) \\ \geq v - p_{nt}^B - \tau(1 - x) + \delta_c \max(v - p_{ot+1}^B - \tau(1 - x), v - p_{nt+1}^A - s - \tau x) \end{aligned} \quad (2.2.1)$$

The marginal newcomer, located at  $x_{t+1}$ , will be just indifferent between the two sequences of purchases when

$$\begin{aligned}
& p_{nt}^A + \tau x_{t+1} + \delta_c \min(p_{ot+1}^A + \tau x_{t+1}, p_{nt+1}^B + s + \tau(1 - x_{t+1})) \\
&= p_{nt}^B + \tau(1 - x_{t+1}) + \delta_c \min(p_{ot+1}^B + \tau(1 - x_{t+1}), p_{nt+1}^A + s + \tau x_{t+1})
\end{aligned} \tag{2.2.2}$$

Since we assume that the regular price is set after the rival's introductory price is known, firm A will always set  $p_{ot+1}^A$  such that its marginal loyal customer at time  $t + 1$  is just indifferent between switching and staying after having purchased from A at time  $t$ . If firm A wants to keep all of its customers in period  $t + 1$ , it will set  $p_{ot+1}^A + \tau x_{t+1} = p_{nt+1}^B + s + \tau(1 - x_{t+1})$ . If it wants to let some customers switch, then it must be true that for firm A's marginal old customer  $p_{ot+1}^A + \tau x_{t+1} > p_{nt+1}^B + s + \tau(1 - x_{t+1})$ . In either case, we have

$$\min(p_{ot+1}^A + \tau x_{t+1}, p_{nt+1}^B + s + \tau(1 - x_{t+1})) = p_{nt+1}^B + s + \tau(1 - x_{t+1}) \tag{2.2.3}$$

Otherwise, firm A can always increase its profits by raising  $p_{ot+1}^A$  without affecting demand from loyal customers. Therefore, the location of the marginal newcomer at time  $t$  can be determined from:

$$\begin{aligned}
& p_{nt}^A + \tau x_{t+1} + \delta_c (p_{nt+1}^B + s + \tau(1 - x_{t+1})) \\
&= p_{nt}^B + \tau(1 - x_{t+1}) + \delta_c (p_{nt+1}^A + s + \tau x_{t+1})
\end{aligned} \tag{2.2.4}$$

This equality determines the location of the marginal newcomer at time  $t$  as well as the distribution of market share at the beginning of period  $t + 1$ :

$$x_{t+1} = \frac{\tau(1 - \delta_c) + \delta_c(p_{nt+1}^A - p_{nt+1}^B) + p_{nt}^B - p_{nt}^A}{2\tau(1 - \delta_c)} \quad (2.2.5)$$

Thus, demand from newcomers can be defined as:

$$q_{1A,t} = x_{t+1} \quad (2.2.6)$$

$$q_{1B,t} = 1 - x_{t+1} \quad (2.2.7)$$

## 2.2.2 Demand from Loyal Customers

The marginal loyal customer for firm A at time  $t$  will be just indifferent between switching and staying. Therefore, her location,  $x_t^l$  can be determined from the equality of the payoffs of each alternative:

$$p_{ot}^A + \tau x_t^l = p_{nt}^B + s + \tau(1 - x_t^l) \quad (2.2.8)$$

This equality yields firm A's demand from loyal customers:

$$q_{AA,t}(p_{ot}^A, p_{nt}^B) = \min \left( \frac{\tau + s + p_{nt}^B - p_{ot}^A}{2\tau}, x_t \right) \quad (2.2.9)$$

Similarly, we can find firm B's demand from loyal customers:

$$q_{BB,t}(p_{ot}^B, p_{nt}^A) = \min \left( \frac{\tau + s + p_{nt}^A - p_{ot}^B}{2\tau}, 1 - x_t \right) \quad (2.2.10)$$

Note that the regular price does not affect demand from newcomers or switchers, so firm  $i$  will choose  $p_{ot}^i$  independent of its own choice of  $p_{nt}^i$ . Thus, each firm sets  $p_{ot}^i$  to maximize profits from loyal customers taking as given the rival's introductory price. Since we assume that firms set  $p_{ot}^i$  after observing  $p_{nt}^j$ , the choice of  $p_{ot}^i$  determines the optimal mass of loyal customers that a firm would like to keep given the introductory price of its rival. If this optimal mass exceeds the firm's actual market share, sales to loyal customers are limited to the size of the firm's existing customer base. For  $c = 0$  firm A's problem with respect to  $p_{ot}^A$  can be set up as follows:

$$\max_{p_{ot}^A} p_{ot}^A \min \left( \frac{\tau + s + p_{nt}^B - p_{ot}^A}{2\tau}, x_t \right) \quad (2.2.11)$$

Given the rival's introductory offer,  $p_{nt}^B$ , the optimal regular price for firm A is:

$$p_{ot}^A(p_{nt}^B) = \max \left( \frac{\tau + s + p_{nt}^B}{2}, \tau + s + p_{nt}^B - 2\tau x_t \right) \quad (2.2.12)$$

Note that the optimal regular price is increasing in the rival's introductory offer.<sup>8</sup> In fact, if  $p_{nt}^B$  is sufficiently large, firm A would keep all of its previous customers as loyal customers so  $q_{AA,t}$  will be constrained by firm A's market share. On the other hand, if  $p_{nt}^B$  is low enough, firm A's loyal customer segment will be less than  $x_t$ .

In the cases where sales to loyal customers are less than a firm's market share

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<sup>8</sup>For an arbitrary level of the marginal cost, the optimal regular price depends on  $c$  if sales to loyal customers are less than the firm's market share:

$$p_{ot}^A(p_{nt}^B) = \max \left( \frac{c + \tau + s + p_{nt}^B}{2}, \tau + s + p_{nt}^B - 2\tau x_t \right)$$

we define  $\hat{q}_{ii,t}$  as firm  $i$ 's optimal sales to loyal customers in period  $t$ . We can further extend the interpretation of  $\hat{q}_{ii,t}$  as firm  $i$ 's optimal market share in period  $t$  if we consider situations in which the acquisition of market share is costly (i.e. when the introductory price is below cost). Upon finding a deterministic optimal path for  $p_{nt}^A$  and  $p_{nt}^B$ , each firm can project how much market share it would like to capture today in order to maximize profits from loyal customers tomorrow. We can find  $\hat{q}_{AA,t}$  by plugging  $p_{ot}^A(p_{nt}^B)$  into (2.2.9) which yields firm A's optimal market share as a function of the rival's introductory price only:

$$\hat{q}_{AA,t}(p_{nt}^B) = \frac{\tau + s + p_{nt}^B}{4\tau} \quad (2.2.13)$$

Firm A's sales to loyal customers and the resulting profits can be summarized as follows:

$$q_{AA,t}(p_{nt}^B) = \min(\hat{q}_{AA,t}(p_{nt}^B), x_t) \quad (2.2.14)$$

$$\Pi_{ot}^A(p_{nt}^B) = \max\left(\frac{(\tau + s + p_{nt}^B)^2}{8\tau}, (\tau + s + p_{nt}^B - 2\tau x_t)x_t\right) \quad (2.2.15)$$

Similarly, we find firm B's optimal regular price, sales to loyal customers and

profits:

$$p_{ot}^B(p_{nt}^A) = \max \left( \frac{\tau + s + p_{nt}^A}{2}, \tau + s + p_{nt}^A - 2\tau(1 - x_t) \right) \quad (2.2.16)$$

$$\hat{q}_{BB,t}(p_{nt}^A) = \frac{\tau + s + p_{nt}^A}{4\tau} \quad (2.2.17)$$

$$q_{BB,t}(p_{nt}^A) = \min \left( \hat{q}_{BB,t}(p_{nt}^A), 1 - x_t \right) \quad (2.2.18)$$

$$\Pi_{ot}^B(p_{nt}^A) = \max \left( \frac{(\tau + s + p_{nt}^A)^2}{8\tau}, (\tau + s + p_{nt}^A - 2\tau(1 - x_t)) (1 - x_t) \right) \quad (2.2.19)$$

From (2.2.12) and (2.2.16) we can see that the optimal regular price is uniquely determined given knowledge of the rival's introductory price. The assumption that firms set introductory and regular prices sequentially ensures that once the introductory prices are announced and firms set their regular prices accordingly, neither firm has a profitable deviation in changing its regular price. Without this assumption, there may not be pure-strategy equilibria if the prior distribution of the market is sufficiently unequal. To see this, observe from (2.2.12) and (2.2.13) that when market share is not a binding constraint on sales to loyal customers, the regular price and sales to loyal customers are increasing in the rival's introductory price. Consider a setting where regular prices are set simultaneously with the introductory price of the rival. Suppose that firm B starts the period with a relatively high market share and charges a low introductory price. Firm A's best response would be to charge a low regular price as well in order to retain some of its clientele. But it is possible that as firm A charges a low regular price it still retains all of its old customers because of their close proximity to A (since we assumed that firm A's

market share is low), so firm B's best response may be to raise its introductory price and target newcomers only, to which firm A's best response will be to raise its regular price as well. Realizing that it can now profitably poach firm A's customers, firm B's best response would be to lower its price again, giving rise to another cycle of price cuts. So, when regular prices and introductory prices are set simultaneously an equilibrium in pure strategies may not exist.<sup>9</sup>

### 2.2.3 Demand from Switchers

Demand from switchers, if positive, can be represented as the difference between the rival's market share and its optimal sales of loyal customers. For firm A, demand from switchers is given by

$$q_{BA,t} = \max(0, (1 - x_t) - \hat{q}_{BB,t}) \quad (2.2.20)$$

Using (2.2.13), we find:

$$q_{BA,t}(x_t) = \max\left(0, \frac{3\tau - s - p_{nt}^A}{4\tau} - x_t\right) \quad (2.2.21)$$

Similarly, demand from switchers for firm B is given by:

$$q_{AB,t} = \max(0, x_t - \hat{q}_{AA,t}) \quad (2.2.22)$$

$$q_{AB,t}(x_t) = \max\left(0, x_t - \frac{\tau + s + p_{nt}^B}{4\tau}\right) \quad (2.2.23)$$

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<sup>9</sup>This is the same argument as applied in Villas-Boas (1999), pp. 611. At this point my model follows closely the setup in Villas-Boas and my introduction of switching costs does not preclude the need to assume sequential price setting with respect to regular prices.



From the demand equations in (2.2.21) and (2.2.23), it is clear that a firm's ability to poach depends on the pre-existing distribution of market shares, summarized in  $x_t$ . The firm that enters the period with low market share can attract the rival's previous customers at a higher price because of the closer proximity of prospective switchers. At the same time, both newcomers and switchers are offered the same price,  $p_{nt}$ , so each firm chooses its optimal introductory price by balancing the incentives to gain market share and to maximize profits from poaching. Given the symmetry of the problem, it is clear that if the firms' only goal was to capture market share, their introductory prices would be equal. It is the incentive to poach that drives a wedge between the firms' introductory prices, unless market share is equally split at the beginning of the period.

#### 2.2.4 Equilibrium Concept

Since current market share depends on the introductory prices from the previous period only,  $x_t$  is the only payoff-relevant state variable that affects the optimal introductory prices in period  $t$ . We will refer to  $x_t$  as the state variable in period  $t$  while  $p_{nt}^A$  and  $p_{nt}^B$  will represent the choice variables for firm A and firm B, respectively. The optimal regular price is unique for a given introductory price, so identifying the optimal pricing strategies for  $p_{nt}^i$  is sufficient to derive the full schedule of prices in period  $t$  as well as the distribution of market share in period  $t + 1$ . We solve the dynamic problem for each firm by looking for a Markov Perfect Equilibrium (MPE), in which firms' pricing strategies depend solely on the realized

distribution of the newcomers' market shares in the previous period. Based on the solution of a similar problem in Villas-Boas (1999), we look for a MPE, in which the price strategies regarding  $p_{nt}^i$  are piecewise affine in  $x_t$  and the value function of each firm is piecewise quadratic in  $x_t$ .<sup>10</sup> We allow for the possibility that the optimal strategies are piecewise affine because firms may pursue different strategies depending on whether they are able to poach, which in turn depends on the state variable  $x_t$ .<sup>11</sup> Therefore, we specify

$$p_{nt}^A - p_{nt}^B = a_k + b_k x_t \quad (2.2.24)$$

$$p_{nt}^A = e_k + f_k x_t \quad (2.2.25)$$

$$p_{nt}^B = e_k - a_k + (f_k - b_k) x_t \quad (2.2.26)$$

$$V^A(x_t) = \alpha_k^A + \beta_k^A x_t + \gamma_k^A x_t^2 \quad (2.2.27)$$

$$V^B(x_t) = \alpha_k^B + \beta_k^B (1 - x_t) + \gamma_k^B (1 - x_t)^2 \quad (2.2.28)$$

We index each of the undetermined coefficients by  $k$  to indicate that they may be different for different ranges of the state variable. Since we conjecture that the introductory prices are piecewise affine in  $x_t$ , we also write their difference as piecewise affine in  $x_t$ . Using (2.2.5) and applying  $p_{nt+1}^A - p_{nt+1}^B = a_k + b_k x_{t+1}$  where the subscript  $k$  refers to the region containing  $x_{t+1}$ , we can rewrite the market distribution in period  $t + 1$  as a function of the current market distribution:

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<sup>10</sup>Equilibria in non-affine strategies may also exist but they are outside the scope of my study.

<sup>11</sup>In the special case when  $\delta_c = 1$ , the optimal price strategies would be identical for all  $x_t$ .

$$x_{t+1}(x_t) = \frac{\tau(1 - \delta_c) + \delta_c a_k + p_{nt}^B(x_t) - p_{nt}^A(x_t)}{2\tau(1 - \delta_c) - \delta_c b_k} \quad (2.2.29)$$

Finally, using  $\delta_f \in (0, 1]$  to indicate the firms' discount factor, we write out the firms' optimization problems with respect to  $p_{nt}^i$ :

$$\begin{aligned} V^A(x_t) = & \max_{p_{nt}^A} \max \left( \frac{(\tau + s + p_{nt}^B)^2}{8\tau}, (\tau + s + p_{nt}^B - 2tx_t)x_t \right) \\ & + p_{nt}^A \cdot \left( x_{t+1}(p_{nt}^A, p_{nt}^B) + \max \left( 0, \frac{3\tau - s - p_{nt}^A}{4\tau} - x_t \right) \right) \\ & + \delta_f V^A(x_{t+1}(p_{nt}^A, p_{nt}^B)) \end{aligned} \quad (2.2.30)$$

$$\begin{aligned} V^B(x_t) = & \max_{p_{nt}^B} \max \left( \frac{(\tau + s + p_{nt}^A)^2}{8\tau}, (s + p_{nt}^A + 2\tau x_t - \tau)(1 - x_t) \right) \\ & + p_{nt}^B \cdot \left( 1 - x_{t+1}(p_{nt}^A, p_{nt}^B) + \max \left( 0, x_t - \frac{\tau + s + p_{nt}^B}{4\tau} \right) \right) \\ & + \delta_f V^B(1 - x_{t+1}(p_{nt}^A, p_{nt}^B)) \end{aligned} \quad (2.2.31)$$

## 2.2.5 Exit Costs

Following Villas-Boas (1999) I assume that there is some minimal level of exit costs that a firm would incur at the end of the period if it does not realize sales to newcomers in that period. Similarly to the assumption that regular prices are set after introductory prices are known, the assumption on exit costs rules out the possibility that a pure-strategy equilibrium may not exist when one firm starts out

the period with a very small market share. For example, it may be more profitable for a firm with low or no market share to set a price that targets switchers only (because it can charge a higher price to rival's customers who are located closer to the firm) rather than compete for newcomers. But then the rival can raise its price as well without giving up too much in demand from newcomers. Given this higher price, the firm with low market share may find it profitable to compete for newcomers as well, so it will lower its price. This will be followed by another price cut by the rival and the first firm may be willing to exit the newcomers' market again. The presence of some minimal level of exit costs eliminates this possibility by ensuring that a firm will always choose to sell to newcomers regardless of how small its market share is.<sup>12</sup> It is important to note that an assumption about exit costs is necessary only for a limited range of the parameter values.

Exit costs are plausible if we assume that firms enter the market with the intention to serve both new and old customers. One example of exit costs could be the erosion of goodwill a firm has if it is based on intergenerational transfer of information about the firm's product. A firm that does not sell to newcomers in a given period may have to compensate for the dissipation of goodwill by taking costly actions to promote its product to newcomers in the next period. Alternatively, we could think of these exit costs as the cost of reentering the market when the firm's market share is zero. The minimal required level of exit costs that would ensure

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<sup>12</sup>Previous models of dynamic competition with switching costs have imposed similar conditions to guarantee the existence of a pure-strategy equilibrium. To (1996) imposes an upper bound on the consumer reservation value while Beggs and Klemperer (1992) impose restrictions on the rate of customer turnover and cost differentials. In both models, these conditions ensure that firms will not pursue a strategy where they do not serve any newcomers.

a pure-strategy equilibrium in my model can be found by setting the maximum discounted payoff from deviating once and selling to switchers only equal to the payoff from staying with the equilibrium strategy and selling to both switchers and newcomers in equilibrium. We denote exit costs by  $E$  and relegate the derivation of their minimal required level to the appendix.

## 2.3 Equilibrium Results

We present two sets of equilibrium results depending on the magnitude of the switching cost. For each equilibrium I characterize the optimal price strategies on the equilibrium path and the resulting pattern of convergence to steady state. I present the intuition of these results in the body of the paper and relegate all technical proofs to the appendix.

### 2.3.1 The Equilibrium under Incomplete Lock-in and Low Switching Costs

In his model of customer recognition in the absence of switching costs, Villas-Boas (1999) shows that when the current distribution of market share is not too uneven, both firms are able to attract some of the rival's previous customers. Based on this result, I conjecture that when switching costs are not too large to preclude switching, there will be incomplete customer lock-in for  $x_t$  close to the middle. I define this range as  $(x_m, 1 - x_m)$  and refer to it as the "poaching region". Upon identifying the optimal price strategies under the conjecture that both firms poach in

equilibrium, I derive  $x_m$  and verify that my conjecture is correct for  $x_t \in (x_m, 1-x_m)$ .

I suppress the subscript  $k$  for all coefficients that define the firms' optimal strategies and value functions for  $x_t \in (x_m, 1-x_m)$ . As long as the problem is symmetric, I also know that the coefficients determining the firms' value functions are identical across the two firms, so I write  $\alpha^A = \alpha^B = \alpha$ ,  $\beta^A = \beta^B = \beta$ ,  $\gamma^A = \gamma^B = \gamma$ .

We modify the value functions for each firm to reflect my conjecture that within the poaching region both firms attract some of the rival's previous customers:

$$\begin{aligned}
V^A(x_t) = & \max_{p_{nt}^A} \max \left( \frac{(\tau + s + p_{nt}^B)^2}{8\tau}, (\tau + s + p_{nt}^B - 2tx_t) x_t \right) & (2.3.1) \\
& + p_{nt}^A \cdot \left( x_{t+1}(p_{nt}^A, p_{nt}^B) + \frac{3\tau - s - p_{nt}^A}{4\tau} - x_t \right) \\
& + \delta_f V^A(x_{t+1}(p_{nt}^A, p_{nt}^B))
\end{aligned}$$

$$\begin{aligned}
V^B(x_t) = & \max_{p_{nt}^B} \max \left( \frac{(\tau + s + p_{nt}^A)^2}{8\tau}, (s + p_{nt}^A + 2\tau x_t - \tau) (1 - x_t) \right) & (2.3.2) \\
& + p_{nt}^B \cdot \left( 1 - x_{t+1}(p_{nt}^A, p_{nt}^B) + x_t - \frac{\tau + s + p_{nt}^B}{4\tau} \right) \\
& + \delta_f V^B(1 - x_{t+1}(p_{nt}^A, p_{nt}^B))
\end{aligned}$$

After finding the best response functions and solving for the undetermined coefficients I obtain the following:

$$a = -\frac{b}{2} \quad (2.3.3)$$

$$f = \frac{b}{2} \quad (2.3.4)$$

The equation characterizing  $b$  is given by:

$$\begin{aligned} & [4b(8\tau - 2\tau\delta_c - \delta_cb) + 16\tau(2\tau - 2\tau\delta_c - \delta_cb)][(2\tau - 2\tau\delta_c - \delta_cb)^2 - \delta_fb^2] \\ & + \delta_fb^3(18\tau - 2\tau\delta_c - \delta_cb) + 16\tau\delta_fb^2(2\tau - 2\tau\delta_c - \delta_cb) = 0 \end{aligned} \quad (2.3.5)$$

In order to derive a tractable solution for  $b$ , I limit attention to the case where  $\delta_c \rightarrow 1$ . All results that refer to the equilibrium with incomplete lock-in are based on this restriction. From (2.3.5) I find that for  $\delta_c \rightarrow 1$ ,  $b \rightarrow 0^-$  and  $\partial b/\partial\delta_c < 0$ .

In the exposition of the firms' problem I assumed that marginal cost is zero. I now generalize the setup presented in the previous section by assuming marginal cost equals  $c \geq 0$ . Proposition 1 below characterizes the firms' optimal price strategies on the equilibrium path within the poaching region.

**Proposition 1.** *Suppose  $\delta_f \geq 0$ ,  $\delta_c \rightarrow 1$ ,  $x_t \in (x_m, 1 - x_m)$ ,  $s \leq \tau$ , and  $E \geq \frac{(3\tau-s)^2 - 2\delta_f(\tau+s)^2}{16\tau}$ . A Markov-perfect equilibrium in affine strategies exists and can be characterized as follows. As  $\delta_c \rightarrow 1$ :*

$$p_{nt}^i \rightarrow c \quad (2.3.6)$$

$$p_{ot}^i \rightarrow c + \frac{\tau + s}{2} \quad (2.3.7)$$

$$\hat{q}_{ii}^i \rightarrow \frac{\tau + s}{4\tau} \quad (2.3.8)$$

$$q_{ij} \rightarrow \frac{\tau - s}{4\tau} \quad (2.3.9)$$

$$x_m \rightarrow \frac{\tau + s}{4\tau} \quad (2.3.10)$$

*In addition to (2.3.3), (2.3.4), and (2.3.5), the relevant coefficients governing the optimal price strategies and the firms' value functions (for  $c$  normalized to zero) are*



given by:

$$e = -\frac{b}{4} + \frac{2\tau^2(1 - \delta_c) + 4\tau(1 - \delta_c) - 3\delta_c b - 4\tau\delta_f\beta - 4\tau\delta_f\gamma}{2(4\tau - 2\tau\delta_c - \delta_c b)} \quad (2.3.11)$$

$$- \frac{s(2\tau - 2\tau\delta_c - \delta_c b)}{2(4\tau - 2\tau\delta_c - \delta_c b)}$$

$$\beta = \frac{(\tau + s + e - a)(f - b)}{4\tau} \quad (2.3.12)$$

$$+ \frac{e(-4\tau(2\tau - 2\tau\delta_c - \delta_c b) + 4\tau(f - b) - f(6\tau - 2\tau\delta_c - \delta_c b))}{4\tau(2\tau - 2\tau\delta_c - \delta_c b)}$$

$$+ \frac{f(10t^2(1 - \delta_c) + 4\tau\delta_c a - 3\tau\delta_c - (2\tau - 2\tau\delta_c - \delta_c b) + 4\tau(e - a))}{4\tau(2\tau - 2\tau\delta_c - \delta_c b)}$$

$$- \frac{fe(6\tau - 2\tau\delta_c - \delta_c b)}{4\tau(2\tau - 2\tau\delta_c - \delta_c b)}$$

$$+ \delta_f\beta \frac{b}{2\tau - 2\tau\delta_c - \delta_c b}$$

$$+ \delta_f\gamma \frac{2b(t(1 - \delta_c) + \delta_c a - a)}{(2\tau - 2\tau\delta_c - \delta_c b)^2}$$

$$\gamma = - \frac{b^2(2\tau - 2\tau\delta_c - \delta_c b)(18\tau - 2\tau\delta_c - \delta_c b) + 16\tau b(2\tau - 2\tau\delta_c - \delta_c b)^2}{32\tau((2\tau - 2\tau\delta_c - \delta_c b)^2 - \delta_f b^2)} \quad (2.3.13)$$

As  $\delta_c \rightarrow 1$ ,  $a \rightarrow 0$ ,  $b \rightarrow 0$ ,  $e \rightarrow 0$ ,  $\beta \rightarrow 0$  and  $\gamma \rightarrow 0$ . The limits of the poaching region,  $x_m$ , are defined as follows:

$$x_m = 1 - \frac{2 \left( M + C^2 - \sqrt{M(M + C^2)} \right) e - C^2(3\tau - s)}{-2 \left( M + C^2 - \sqrt{M(M + C^2)} \right) f - 4\tau C^2} \quad (2.3.14)$$

where

$$C = 2\tau - 2\tau\delta_c - \delta_c b,$$

$$M = 4\tau C - 4\tau\delta_f\gamma$$

In steady state the market is equally distributed,  $\bar{x} = 1/2$  and convergence is governed by

$$x_{t+1} - \frac{1}{2} = \frac{-b}{2t(1 - \delta_c) - \delta_c b} \left( x_t - \frac{1}{2} \right) \quad (2.3.15)$$

where  $-b/(2t(1 - \delta_c) - \delta_c b) \in (2/3, 1)$ .

*Proof.* See Appendix. □

The optimal price strategies described in Proposition 1 have a number of interesting features, which become evident when I consider the limit case where  $\delta_c = 1$ . I refer to consumers with  $\delta_c = 1$  as very patient consumers (all consumers within the market have the same discount factor). When consumers are very patient Proposition 1 indicates that  $a = b = 0$ , which implies that  $p_{nt}^A = p_{nt}^B$  for all possible distributions of  $x_t$ . That is, firms' introductory prices become independent of market share and equal to marginal cost. To provide intuition for this result I present the following lemma:

**Lemma 1.** For  $\delta_c = 1$ ,  $q_{1i,t} = 0$  whenever firm  $i$  deviates from the equilibrium path

proposed in Proposition 1 by setting  $p_{nt}^i > p_{nt}^j$ .

*Proof.* First note that for  $\delta_c = 1$ , we have  $p_{nt}^A = p_{nt+1}^A = p_{nt+1}^B$ . Designate this equilibrium price as  $p$  and note from Proposition 1 that this is true for all  $x_t$  as long as  $\delta_c = 1$ . Let  $p_{nt}^A$  be the deviating price for firm A. A newcomer located at  $x$  will purchase from A if and only if:

$$p_{nt}^A + \tau x + (p + \tau(1 - x) + s) \leq p + \tau x + (p + \tau x + s)$$

$$p_{nt}^A \leq p$$

It is clear that for  $p_{nt}^A > p$ , the inequality above cannot be satisfied for any  $x$ . Therefore, if A deviates to a price above the proposed equilibrium price,  $p$ , it will make no sales to newcomers.  $\square$

The lemma above suggests that demand from newcomers is zero whenever a firm sets its introductory price above the rival's price. Similarly, a firm will capture the entire market of newcomers if it undercuts the rival's price. These results suggest that on the equilibrium path demand from newcomers is perfectly elastic when  $\delta_c = 1$ . This result is also present in Villas-Boas (1999) and is preserved here even when switching costs are positive. There are a number of features present in the model that produce this result - consumers stay in the market for an even number of periods, there is cost and demand symmetry across the two firms, and there is no uncertainty about the realization of consumer preferences in the mature

market. As long as the presence of switching costs does not give rise to asymmetric demand, this property is preserved. In my setting switching costs are symmetric and there is no uncertainty about their realization so demand from newcomers is symmetric across the two firms.

The perfect elasticity of newcomers' demand helps explain the properties of the equilibrium. Recall that we are able to derive tractable representations of the equilibrium price strategies only when we limit attention to  $\delta_c$  close to one, so understanding the equilibrium properties in the limit,  $\delta_c = 1$ , is particularly important. The perfect elasticity of newcomers' demand explains the somewhat surprising result that as  $\delta_c \rightarrow 1$  the introductory price approaches marginal cost despite the heterogeneity of consumer preferences. In fact, as noted in Villas-Boas(1999), competition intensifies as consumers become more patient. To see this, note that using the equilibrium result  $a = -b/2$  we can rewrite  $x_{t+1}$  as follows:

$$\begin{aligned} x_{t+1} &= \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - p_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} \\ &= \frac{1}{2} + \frac{p_{nt}^B - p_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} \end{aligned} \tag{2.3.16}$$

Let  $w = \frac{1}{2\tau - 2\tau\delta_c - \delta_c b}$  indicate the weight of the price differential on the location of the marginal consumer, given by  $x_{t+1}$ . On the equilibrium path  $b \leq 0$  and  $\partial b / \partial \delta_c < 0$ , so  $\partial w / \partial \delta_c > 0$  – as consumer patience increases, the marginal newcomer becomes more sensitive to the difference between the introductory prices offered today.

The result that consumer patience intensifies competition is in contrast with previous results in the literature on switching costs and is due to our assumption about imperfect customer recognition.<sup>13</sup> In models of dynamic competition with switching costs and uniform pricing policies (Beggs and Klemperer, 1992; To, 1996) consumer patience softens the competition for market share. In these models firms charge a uniform price to all customers and switching costs are high enough to preclude switching. As a result, consumers recognize that the low-price firm today will charge a higher price tomorrow because it has a greater incentive to exploit its customer base today rather than invest in market share. In contrast, under customer recognition combined with the assumption that regular prices are conditioned on the introductory prices, the price that an old customer pays increases in the introductory price of the rival, regardless of the decision to switch or stay. I have shown that  $a \rightarrow 0$  and  $b \rightarrow 0$  as  $\delta_c \rightarrow 1$ , so consumers realize that on the equilibrium path the firms' introductory prices next period will be less differentiated as  $\delta_c$  goes up. This increases the importance of the introductory offers in the current period and makes consumers more sensitive to these offers.

Going back to the result that  $p_{nt}^A = p_{nt}^B = c$  when  $\delta_c = 1$ , we observe that this is the same price as derived in Villas-Boas' model where switching costs are zero. It may seem puzzling at first that the introductory price does not fall below cost despite the perfect elasticity of newcomers' demand and the presence of switching costs. To provide intuition for this result, I summarize some important properties

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<sup>13</sup>In subsequent results based on perfect customer recognition, we find the opposite effect – consumer patience relaxes competition.

of the equilibrium described above in the following corollary:

**Corollary 1.** *Along the equilibrium path described in Proposition 1 the following is*

*true for  $\delta_c \rightarrow 1$ :*

$$1) \quad \partial p_n^i / \partial s < 0 \text{ for } \delta_c < 1 \text{ and } \partial p_n^i / \partial s = 0 \text{ for } \delta_c = 1 \quad (2.3.17)$$

$$2) \quad \partial p_o^i / \partial s > 0 \quad (2.3.18)$$

$$3) \quad \partial \hat{q}_{ii} / \partial s > 0 \text{ and } \hat{q}_{ii} \rightarrow \frac{1}{2} \text{ as } s \rightarrow \tau \quad (2.3.19)$$

$$4) \quad \partial x_m / \partial s > 0 \text{ and } x_m \rightarrow \frac{1}{2} \text{ as } s \rightarrow \tau \quad (2.3.20)$$

*Proof.* See Appendix. □

The properties described by (2.3.18) and (2.3.19) show that firms' regular prices and optimal sales to loyal customers increase in the size of the switching costs. Therefore, switching costs raise profits from loyal customers. Furthermore, (2.3.17) indicates that the introductory price is weakly decreasing in  $s$  because market share becomes more valuable as  $s$  goes up and because the barriers to switching are higher. Interestingly, when consumers are very patient the introductory price is independent of the switching cost. This can be explained by result (2.3.19). The equilibrium I characterize in Proposition 1 is valid for  $s \leq \tau$  (conditional on  $\delta_c = 1$ ) and I find that firms' optimal market share,  $\hat{q}_{ii}$ , is no greater than  $1/2$ . When consumers are very patient, firms are unable to charge introductory prices above marginal cost (or they will not make any sales to newcomers) and they are not interested in capturing

more than half of the newcomers' market if this entails pricing below cost. Thus, at  $p_n^i = c$  neither firm has an incentive to undercut the rival's price regardless of the value of  $s$ .

The fact that firms retain less than their share of old customers as loyal customers explains why the equilibrium I derive here is similar to the one in Villas-Boas' model of customer recognition, in which switching costs are zero. As long as switching costs are sufficiently low to allow poaching in equilibrium, we have that  $\hat{q}_{ii} \leq \frac{1}{2}$  – besides increasing the value of market share and decreasing the return to poaching, the presence of some low level of switching costs does not change the nature of competition in the market.

The magnitude of the switching cost does affect the equilibrium level of prices, profits, and the mass of consumers who switch, by varying the relative return on market share acquisition and poaching. To see how  $s$  affects these two competing forces in the determination of the optimal introductory price, I look at the decomposition of the partial derivative of  $p_{nt}^i$  with respect to switching costs. Since  $\partial p_{nt}^A / \partial s = \partial e / \partial s + \partial f / \partial s$  and the latter term is zero we have:

$$\partial e / \partial s = -\frac{2\tau\delta_f}{2\tau + C} \cdot \partial\beta / \partial s - \frac{C}{4\tau + 2C} \quad (2.3.21)$$

The first term in this expression captures the impact of the value of market share ( $\beta$ ) as a function of  $s$  on the introductory price. In the proof of Corollary 1 I show that  $\partial\beta / \partial s \geq 0$  and  $C = 2\tau - 2\tau\delta_c - \delta_cb \rightarrow 0^+$  as  $\delta_c \rightarrow 1$ . As switching costs increase, market share becomes more valuable ( $\partial\beta / \partial s \geq 0$ ) and patient firms lower

their introductory offers accordingly. The second term in  $\partial e/\partial s$  depends solely on  $b$  and captures the effect of the incentive to poach. Recall that  $f = b/2$  and  $p_{nt}^A = e + fx_t$ , so a higher  $b$  indicates that market share becomes more important in determining  $p_n$ . Thus,  $b$  can be viewed as a proxy of the magnitude of the incentive to poach. It is straightforward to show that  $\partial C/\partial b < 0$ , so the absolute value of  $-C/(4\tau + 2C)$  increases as  $b$  goes up – a strong incentive to poach has a larger negative impact on the equilibrium  $p_n$  through  $s$  because firms have to offer larger discounts to compensate switchers for the cost of switching. In fact, newcomers benefit from the ongoing competition for switchers because the firms’ incentive to poach reduces introductory prices even further. Only in the limit as  $\delta_c \rightarrow 1$  we have  $\frac{C}{4\tau+2C} \rightarrow 0$  – the incentive to poach no longer affects the equilibrium introductory price.

When  $\delta_c < 1$  the determination of the introductory offers hinges on the trade-off between poaching and investing in market share and the size of the incoming cohort of consumers matters. If consumers are fairly impatient and there is a large cohort of newcomers (relative to the old cohort of consumers, some of which are switchers today), the equilibrium introductory price may be quite high as poaching becomes relatively less important. If there is only a small mass of newcomers in the market, firms may forgo the high profit margin on newcomers and lower their prices to attract more switchers. When consumers are very patient, we have shown that  $p_n$  converges to marginal cost, reducing the profit margin on switchers and newcomers to zero. In this case, if the size of the newcomers cohort is relatively small, a firm may find a profitable deviation in raising its price and targeting switchers only. This



will give rise to an equilibrium in mixed strategies where firms randomize between charging a high price targeted at switchers and undercutting the rival's price to attract newcomers, resulting in higher introductory prices on average. Thus, a small incoming cohort of consumers may either raise or lower prices depending on the degree of consumer patience. We can also conclude that fast growing markets with large incoming cohorts of very patient consumers can more easily sustain introductory offers close to marginal cost (even in the absence of exit costs) because a larger volume of sales to newcomers counteracts the temptation to raise prices and target switchers only.

From (2.3.17) and (2.3.18) it is clear that customer recognition alone gives rise to a 'bargain-then-rip-off' price pattern that is typical of switching costs models.<sup>14</sup> Switching costs further amplify the resulting loyalty price premium,  $p_{ot} - p_{nt}$ . Using (2.2.12) and adjusting for  $c > 0$ , we see that

$$\begin{aligned}
 p_{ot} - p_{nt} &= \frac{c + \tau + s + p_{nt}}{2} - p_{nt} & (2.3.22) \\
 &= \frac{\tau + s}{2} - \frac{p_{nt} - c}{2} \\
 &\rightarrow \frac{\tau + s}{2} \text{ as } \delta_c \rightarrow 1
 \end{aligned}$$

Finally, for  $\delta_c \rightarrow 1$  we can derive the impact of switching costs on profits. Firm  $i$ 's profits per cohort of consumers entering the market in period  $t$  are given by

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<sup>14</sup>See Section 2.3.1 in Farrell & Klemperer 2007 for a thorough discussion of such models.

$$\Pi_t^i(x_t) = (p_{nt}^i - c)(q_{1i} + q_{ji}) + \delta_f (p_{ot+1} - c) (q_{ii}) \quad (2.3.23)$$

$$\frac{\partial \Pi_t^i}{\partial s} = \frac{\partial p_{nt}^i}{\partial s} (q_{1i} + q_{ji}) + (p_{nt}^i - c) \frac{\partial q_{ji}}{\partial s} + \delta_f \left[ \frac{\partial p_{ot+1}^i}{\partial s} q_{ii} + (p_{ot+1}^i - c) \frac{\partial q_{ii}}{\partial s} \right] \quad (2.3.24)$$

$$\rightarrow \delta_f \left[ \frac{1}{2} q_{ii} + \frac{\tau + s}{2} \frac{\partial q_{ii}}{\partial s} \right] \quad \text{as } \delta_c \rightarrow 1 \quad (2.3.25)$$

From Proposition 1 and Corollary 1 we can see that  $\partial p_n^i / \partial s \rightarrow 0$  and  $p_n^i - c \rightarrow 0$  as  $\delta_c \rightarrow 1$  while  $\partial p_o^i / \partial s > 0$  and  $\partial q_{ii} / \partial s > 0$  for all  $\delta_c$ . Therefore, in the limit firm profits increase in the size of the switching costs and reach a steady-state maximum of  $\frac{\delta_f \tau}{2}$  as  $s \rightarrow \tau$ . Note, however, that this is the minimum level of profits in this market because prices are decreasing in  $\delta_c$  and I evaluate the profit function at  $\delta_c \rightarrow 1$ . In the standard Hotelling model profits from a generation of customers who make a purchase twice would equal  $\frac{(1+\delta_f)\tau}{2}$ . Compared to that level, profits in a market with customer recognition, low switching costs and very patient consumers are always lower. Based on the same result for  $s = 0$  and  $\tau = 1$ , Villas-Boas (1999) concludes that firms would be better off if they did not recognize their previous customers. Chen (1997) reaches the same conclusion for a homogeneous market with heterogeneous switching costs and customer recognition. In the current setting, we see that switching costs can alleviate the disparity in profits. Unfortunately, the literature does not provide us with a basis of comparison to determine if customer recognition alone leads to lower profits relative to uniform pricing when switching

occurs in equilibrium.

Corollary 1 also states that the presence of switching costs shrinks the ‘poaching’ region given by  $(x_m, 1 - x_m)$ . I identify this region by looking for the range of  $x_t$  such that neither firm has a profitable deviation in a price strategy that does not attract switchers. I find that firm A will not deviate from the equilibrium strategy described in Proposition 1 if  $x_t \leq 1 - x_m$  and, similarly, firm B will not deviate if  $1 - x_t \leq 1 - x_m$ . Intuitively, these restrictions follow from the fact a firm with large market share has to charge a lower introductory price in order to poach. If the firm’s market share is sufficiently large and  $\delta_c < 1$ , the desire to poach will lower  $p_n$  to a level, at which the firm is better off raising its price and selling to newcomers only. Since higher switching costs lower the payoff from poaching, a deviation to a no-poaching strategy becomes profitable at lower levels of market share. As the poaching region contracts, bilateral switching becomes less likely to be observed in equilibrium. As (2.3.20) shows, the poaching region shrinks to a mass of zero as switching costs approach  $\tau$  and  $\delta_c \rightarrow 1$  and poaching becomes unfeasible.

When the market is very unevenly distributed, i.e.  $x_t$  is outside  $(x_m, 1 - x_m)$ , only the firm with the smaller market share engages in poaching while its rival pursues a no-poaching strategy. Villas-Boas (1999) investigates in detail the market dynamics outside the poaching region for  $\delta_c < 1$  and finds that it takes no more than two periods for the market to enter the poaching region. If market share falls in the ‘very small’ region,  $x_t \in [0, x_s]$ , only firm A poaches; next period the market enters the ‘small’ region, given by  $(x_s, x_m)$ , where A poaches and B does not, and in the next period market share is such that  $x_t \in (x_m, 1 - x_m)$  and both firms

poach. When switching costs are low, the market will follow a similar path before entering the poaching region. Switching costs will affect the boundary  $x_s$ , which will affect the probability that  $x_t$  falls within the ‘very small’ region and that it will take an additional period before entering the poaching region. Since convergence to steady state may be rather slow in this region, a change in the probability that the market takes an additional period to enter the poaching region does not seem to be significant enough to merit a detailed investigation of how  $s$  affects  $x_s$ . For this reason, I do not characterize the equilibrium price strategies in the ‘small’ and ‘very small’ regions. I note, however, that when  $\delta_c = 1$  the price strategies outlined in Proposition 1 constitute an equilibrium for all  $x_t$  and convergence to steady-state occurs in just one period from all possible realization of market share. This occurs because the perfect elasticity of newcomers’ demand implies that both firms would set their introductory prices equal to marginal cost regardless of  $x_t$ .

The market dynamics for  $\delta_c < 1$  are governed by the equation defining  $b$  in (2.3.5). Note that  $s$  does not enter (2.3.5) and, hence, within the no-poaching region switching costs do not impact the speed of convergence to steady state. Villas-Boas (1999) shows that convergence is monotonic and may take a large number of periods. Thus, the incumbent firm preserves its incumbency advantage in terms of market share and this result is unaffected by the presence of switching costs as long as the latter are not too high to prevent switching. However, the ultimate impact of the incumbency advantage is unclear. Entering the period with larger market share benefits the incumbent because the rival is setting a higher introductory price allowing the incumbent to set a higher regular price and retain more regular cus-

tomers. However, large market share also hurts profitability because it implies a lower introductory price – the incumbent has a lower profit margin on new customers. When  $\delta_c = 1$  incumbency advantages in terms of market share disappear within one period, while incumbency advantages in terms of profits are zero.

### 2.3.2 Equilibrium Results under Complete Lock-in

When  $s > \delta_c \tau$  and  $\delta_c \rightarrow 1$ , the price strategies described in Proposition 1 no longer constitute an equilibrium because bilateral poaching is not feasible. I now conjecture that when switching costs exceed the threshold  $\delta_c \tau$ , there will be a middle region for  $x_t$ , within which each firm retains its entire previous clientele. When switching costs are very high, this region will extend to the entire market - all customers will be locked-in to their original supplier for all  $x_t$ . Such high switching costs are normally assumed to exist in the dynamic models of uniform pricing (Beggs and Klemperer, 1992; To, 1996).

Under complete customer lock-in, both firms will pursue price strategies targeting newcomers and loyal customers only. Assuming (and later verifying) that next period the distribution of the market falls within the same no-poaching region, we can modify the firms' value functions as follows:

$$\begin{aligned}
V^A(x_t) &= \max_{p_{nt}^A} (\tau + s + p_{nt}^B - 2tx_t)x_t & (2.3.26) \\
&+ p_{nt}^A \cdot x_{t+1}(p_{nt}^A, p_{nt}^B) \\
&+ \delta_f V^A(x_{t+1}(p_{nt}^A, p_{nt}^B))
\end{aligned}$$

$$\begin{aligned}
V^B(x_t) &= \max_{p_{nt}^B} (s + p_{nt}^A + 2\tau x_t - \tau)(1 - x_t) & (2.3.27) \\
&+ p_{nt}^B \cdot (1 - x_{t+1}(p_{nt}^A, p_{nt}^B)) \\
&+ \delta_f V^B(1 - x_{t+1}(p_{nt}^A, p_{nt}^B))
\end{aligned}$$

Solving for the firms' best response functions and checking for deviations, we can characterize the equilibrium price strategies under complete lock-in in Proposition 2:

**Proposition 2.** *Suppose  $\delta_c \in (0, 1)$ ,  $\delta_f \in (0, 1)$ ,  $x_t \in (\tilde{x}_m, 1 - \tilde{x}_m)$ , and  $s > \delta_c \tau$ .*

*A Markov-perfect equilibrium in affine strategies exists and can be characterized as*

follows:

$$p_{nt}^A = p_{nt}^B = c - \frac{\delta_f s - (1 - \delta_c + \delta_f)\tau}{1 + \delta_f}, \quad (2.3.28)$$

$$p_{ot}^A = p_{ot}^B = c + \tau + \frac{s - \delta_c \tau}{1 + \delta_f}, \quad (2.3.29)$$

$$q_{AA} = x_t \quad q_{BB} = 1 - x_t, \quad q_{AB} = q_{BA} = 0 \quad (2.3.30)$$

$$x_{t+1} = \bar{x} = \frac{1}{2} \quad (2.3.31)$$

$$(2.3.32)$$

The limits of the no-poaching region,  $(\tilde{x}_m, 1 - \tilde{x}_m)$  are defined as follows:

$$\tilde{x}_m = \max(0, 1 - \hat{q}_{BB}, \hat{x}_m) \quad (2.3.33)$$

where

$$\hat{q}_{BB} = \frac{\tau + s + p_{nt}^A}{4\tau} \quad (2.3.34)$$

$$\hat{x}_m = \frac{3\tau - s}{4\tau} - \frac{2(\sqrt{M(M + C^2)} - M)p_{nt}^A}{4tC^2} \quad (2.3.35)$$

$$C = 2\tau(1 - \delta_c) \quad (2.3.36)$$

$$M = 4\tau C - 4\tau\delta_f\gamma \quad (2.3.37)$$

The relevant coefficients governing the optimal price strategies and the firms' value

functions (for  $c$  normalized to zero) are given by:

$$a = b = f = 0 \tag{2.3.38}$$

$$e = \frac{(1 - \delta_c + \delta_f)\tau - \delta_f s}{1 + \delta_f} \tag{2.3.39}$$

$$\beta = \frac{(2 + \delta_f - \delta_c)\tau + s}{1 + \delta_f} \tag{2.3.40}$$

$$\gamma = -2\tau \tag{2.3.41}$$

*Proof.* See Appendix. □

Proposition 2 characterizes the equilibrium in the no-poaching region,  $(\tilde{x}_m, 1 - \tilde{x}_m)$ . First, note that the equilibrium price strategies are independent of market share ( $f = b = 0$ ) for all values of  $\delta_c \in (0, 1)$ . This is in contrast to previous models of dynamic competition with switching costs. Beggs and Klemperer (1992), Padilla (1992) and To (1995) establish that in the presence of switching costs prices are increasing in market share because the firm with higher market share has a stronger incentive to exploit its customer base and forgo investment in future market share. All three of these models, however, consider firms that charge uniform prices to all customer segments. In a setting where firms can price discriminate on the basis of purchase history, there is no tradeoff between exploiting one's clientele and investing in future market share. The main factor that drives this result is the fact that within  $(\tilde{x}_m, 1 - \tilde{x}_m)$  neither firm can poach. In our setting poaching is the only channel that establishes a relationship between the introductory price and market share. When firms realize that they cannot successfully poach in equilibrium, their only



objective in selecting  $p_{nt}$  is to compete for newcomers and this renders market share irrelevant. Hence, customer recognition in the presence of switching costs, which are sufficiently high to induce complete customer lock-in, breaks up the relationship between introductory prices and market share. For the same reason, we see that  $a = b = 0$  for all  $x_t$  within the no-poaching region. This is also true in the equilibrium with low switching costs and incomplete lock-in but only when  $\delta_c = 1$  since in the latter case poaching is profit-neutral.

While the inability to poach explains  $f = b = 0$ , the symmetry of the problem explains the fact that  $a = 0$  - firms' introductory prices will always be identical. From this it is clear that within the no-poaching region, convergence to steady state will occur in just one period. In addition, when switching costs are sufficiently high, the no-poaching region encompasses the entire market so Proposition 2 and the convergence result extend to all values of  $x_t$ . I present this result in the following corollary:

**Corollary 2.** *If  $s \geq \max((2 + \delta_c + 2\delta_f)\tau, \min(\bar{s}_1, \bar{s}_2, \bar{s}_3))$ , the no-poaching region extends to the entire unit interval and the market converges to steady state in just one period from all  $x_t$  in  $[0, 1]$ .*

*Proof.* See Appendix. □

The condition on  $s$  outlined here is sufficient to ensure that  $\tilde{x}_m = 0$ , so that there is complete customer lock-in for all possible distributions of the market. This guarantees that the introductory prices will be independent of  $x_t$  and convergence will take place within one period for all  $x_t$ . This result has important implications

for the incumbency advantages in the market. Despite the fact that a single firm can lock in all old customers due to switching costs, it loses any incumbency advantages from possessing larger market share in just one period upon entry by a rival firm. Furthermore, from Proposition 2 we can see that the value function of each firm increases in  $s$  through  $\beta$ , the value of market share. Thus, switching costs facilitate market entry not only because the incumbent loses her dominant position in just one period, but also because the value of entering the market is higher.

Similar to the equilibrium with incomplete lock-in and  $\delta_c$  away from one, the introductory prices we derive under complete lock-in decrease in the level of switching costs and fall as consumers become more patient and competition intensifies. Furthermore, the equilibrium  $p_n$  falls below cost when switching costs are sufficiently high:  $p_{nt}^i < c \Leftrightarrow s > (1 - \delta_c + \delta_f)\tau/\delta_f$ . Recall that under complete lock-in, firms are competing for more than half of the newcomers' market because at the proposed equilibrium prices the optimal sales to loyal customers next period exceed one-half. The optimal regular price is increasing in  $s$ , so switching costs increase the value of market share. Similar to the equilibrium with low switching costs, the loyalty price premium is increasing in  $s$  but it is also decreasing in the firm's market share because the regular price under complete lock-in depends on  $x_t$ :

$$p_{ot}^A - p_{nt}^A = s + 2\tau(1/2 - x_t) \quad (2.3.42)$$

$$p_{ot}^B - p_{nt}^B = s + 2\tau(x_t - 1/2) \quad (2.3.43)$$

From (2.3.28) and (2.3.29) we see that firms compete away all rents associated

with the presence of switching costs – the introductory price offers a discount of  $\frac{\delta_f s}{(1+\delta_f)}$ , which is extracted next period in the form of a price premium conditional on  $s$ , i.e.  $\frac{s}{(1+\delta_f)}$ . As a result, firm profits per cohort of consumers are independent of the magnitude of the switching costs:

$$\begin{aligned}\Pi(\bar{x}) &= p_{nt}^i(1/2) + \delta_f [p_{ot}^i(1/2)] \\ &= \frac{1 - \delta_c + \delta_f}{2} \tau\end{aligned}\tag{2.3.44}$$

It should also be noted that there is no pure-strategy equilibrium for  $\delta_c = 1$ . This is due to the market property that newcomers demand becomes perfectly elastic as consumers become very patient. When newcomers demand is perfectly elastic and firms compete for more than half of the market as is the case when  $s > \delta_c \tau$ , each firm has an incentive to undercut the rival by  $\epsilon \rightarrow 0$  in order to capture the entire market and realize a discrete gain in profits. In contrast, under incomplete lock-in firms anticipated that they will keep less than half of the market as loyal customers and did not have a profitable deviation in undercutting when demand was perfectly elastic.

Per-cohort profits are increasing in the degree of product differentiation, decrease in consumer patience and are at most equal to  $\tau$ . This profit level is equivalent to the level of profits in a Hotelling model with no switching costs and no customer recognition. Since switching costs do not affect profits and only act as a barrier to switching, this result is largely driven by the presence of customer recognition. Similar to the result in Chen (1997), we find that in steady state firms are worse

off under customer recognition than under uniform pricing since in the latter case the equilibrium price is above the standard Hotelling price, as shown in Beggs and Klemperer (1992) and To(1996).

Figure 2.1 shows the relationship between steady-state profits and switching costs under complete and incomplete lock-in conditional on  $\delta_c \rightarrow 1$ . I choose to set  $\delta_c = .99$  because the equilibrium with incomplete lock-in is only analyzed for  $\delta_c \rightarrow 1$  and we need to compare firm profits under the equilibrium paths conditional on the same parameter values. The positively-sloped section of the profit function in Figure 2.1 illustrates that profits under incomplete lock-in are increasing in the size of the switching cost. When switching costs are low and both firms find it optimal to poach, firms anticipate that they will keep less than their market share as loyal customers next period and competition for newcomers is not as intense as under complete lock-in. As a result, the introductory price does not fall below cost (despite the presence of switching costs) and profits increase in  $s$ . When switching costs approach the threshold  $\delta_c \tau$ , per-cohort profits approach their peak level. As soon as switching costs exceed the threshold  $\delta_c \tau$ , firms find it optimal to keep all of their attached customers and complete customer lock-in intensifies completion. Firms undercut until they dissipate all rents from the presence of switching costs and, profits become independent of  $s$ . Nevertheless, steady-state profits per cohort remain positive because of the underlying product differentiation. Firms undercut until they dissipate all rents from the presence of switching costs and, profits become independent of  $s$ . Nevertheless, steady-state profits per cohort remain positive because of the underlying product differentiation. Finally, profits are decreasing in

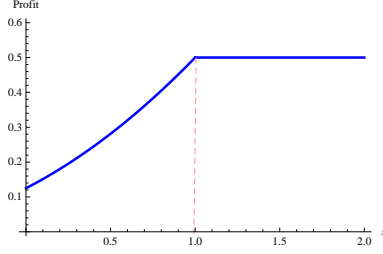


Figure 2.1: Steady-state profits per cohort ( $\delta_c = .99$ ,  $\delta_f = 1$ ,  $\tau = 1$ )

consumer patience because newcomers' demand becomes more elastic as  $\delta_c$  goes up and this puts downward pressure on the introductory price (regular prices are also increasing in the introductory price). Therefore, the profit levels in Figure 2.1 should be interpreted as showing the minimum level of steady-state per-cohort profits in a market with switching costs and customer recognition.

Finally, I draw attention to the continuity of the equilibrium results with respect to  $s$  by assuming  $\delta_c \rightarrow 1$ , in which case the threshold level for  $s$ , - the level that determines whether we have an equilibrium with switching or not, - is approaching  $\tau$ . We have shown in Proposition 1 that for  $s \rightarrow \tau^-$  and  $\delta_c \rightarrow 1$ , the optimal introductory price converges to marginal cost from above. From Proposition 2 it can be seen that for  $\delta_c \rightarrow 1$ ,  $p_n \rightarrow c - \delta_f(s - \tau)/(1 + \delta_f)$  - as  $s \rightarrow \tau^+$ , the equilibrium introductory price approaches marginal cost from below. Also, when  $\delta_c \rightarrow 1$ ,  $\hat{q}_{ii} \rightarrow (\tau + s)/(4\tau)$  (from (2.3.8)) when  $s \leq \delta_c\tau$  and  $\hat{q}_{ii} \rightarrow 1/2$  as  $s \rightarrow \tau$ . Similarly, we can show that under complete lock-in,  $\hat{q}_{ii} \rightarrow 1/2$  as  $s \rightarrow \tau^+$ . We can find  $\hat{q}_{ii}$  under complete lock-in by plugging in the equilibrium  $p_{nt}$  into (2.2.13).<sup>15</sup>

<sup>15</sup>Note that in finding (2.2.13) I assumed that marginal cost is normalized to zero so I adopt the same assumption in deriving  $\hat{q}_{ii}$  here

$$\begin{aligned}\hat{q}_{AA} &= \frac{\tau + s - \frac{\delta_f(s-\tau)}{1+\delta_f}}{4\tau} \\ &= \frac{(1 + 2\delta_f)\tau + s}{4\tau(1 + \delta_f)}\end{aligned}\tag{2.3.45}$$

As switching costs approach the threshold value, the introductory price approaches marginal cost and firms' optimal market share approaches one-half. Once switching costs exceed that threshold,  $p_n$  falls below cost because firms now compete for more than half of the market of newcomers. Steady-state profits peak as switching costs reach  $\delta_c\tau$  and level off for higher levels of  $s$ .

### 2.3.3 The Equilibrium under Incomplete, Asymmetric Lock-in and High Switching Costs

I now present the equilibrium price strategies when the no-poaching region does not encompass the entire market. Suppose that firm B starts period  $t$  with low market share such that  $x_t \in (1 - \tilde{x}_m, 1)$ . In this case, firm B will not play the strategy outlined in Proposition 2 because it has a profitable deviation in choosing a poaching strategy. Therefore, I conjecture that in period  $t$  firm B is able to poach some of A's previous customers while retaining its entire customer base. I further suppose that next period the market moves into the no-poaching region characterized by Proposition 2, which is true for a wide range of parameter values. Under these assumptions, I designate the value function of a firm outside the no-

poaching region as  $V_1^i$  where the subscript  $1$  indicates the relevant range of  $x_t$  such that unilateral poaching occurs for one period only (since I assume that next period the market distribution falls within the no-poaching region). Thus, the affine functions governing the equilibrium price strategies in this region for period  $t$  are given by:

$$p_{nt}^A - p_{nt}^B = a_1 + b_1 x_t \quad (2.3.46)$$

$$p_{nt}^A = e_1 + f_1 x_t \quad (2.3.47)$$

$$p_{nt}^B = e_1 - a_1 + (f_1 - b_1) x_t \quad (2.3.48)$$

$$V^A(x_t) = \alpha_1 + \beta_1 x_t + \gamma_1 x_t^2 \quad (2.3.49)$$

$$V^B(x_t) = \alpha_1 + \beta_1 (1 - x_t) + \gamma_1 (1 - x_t)^2 \quad (2.3.50)$$

Since I suppose that  $x_{t+1} \in (\tilde{x}_m, 1 - \tilde{x}_m)$ , next period prices will be governed by the coefficients valid for the no-poaching region ( $p_{nt+1}^A - p_{nt+1}^B = a + b x_{t+1}$  and so on).

I modify the value functions accordingly:

$$\begin{aligned}
V_1^A(x_t) &= \max_{p_{nt}^A} \frac{(\tau + s + p_{nt}^B)^2}{8\tau} & (2.3.51) \\
&+ p_{nt}^A \cdot x_{t+1}(p_{nt}^A, p_{nt}^B) \\
&+ \delta_f (\alpha + \beta x_{t+1} + \gamma x_{t+1}^2)
\end{aligned}$$

$$\begin{aligned}
V_1^B(x_t) &= \max_{p_{nt}^B} (s + p_{nt}^A + 2\tau x_t - \tau) (1 - x_t) & (2.3.52) \\
&+ p_{nt}^B \cdot \left( 1 - x_{t+1}(p_{nt}^A, p_{nt}^B) + x_t - \frac{\tau + s + p_{nt}^B}{4\tau} \right) \\
&+ \delta_f (\alpha + \beta(1 - x_{t+1}) + \gamma(1 - x_{t+1})^2)
\end{aligned}$$

Solving for the best response functions and checking for deviations, I find an equilibrium in pure strategies for some, though not all, parameter values. I characterize the MPE in pure strategies in Proposition 3:

**Proposition 3.** *Suppose  $\delta_c \in (0, 1)$ ,  $\delta_f \in (0, 1)$ ,  $x_t \in (\max(1 - \tilde{x}_m, 1 - \tilde{x}_s), 1)$ ,  $s \in (\delta_c\tau, (2 + \delta_c + 2\delta_f)\tau)$  and  $x_{t+1} \in (\tilde{x}_m, 1 - \tilde{x}_m)$ . A Markov-perfect equilibrium in pure*



strategies exists and can be characterized as follows:

$$\begin{aligned} \hat{p}_{nt}^A = & \frac{(7 - 2\delta_c^3 + 13\delta_f + 6\delta_f^2 + \delta_c^2(11 + \delta_f) + 2\delta_c(-8 - 7\delta_f + \delta_f^2))\tau}{2(1 + \delta_f)(5 + 2\delta_c^2 + 6\delta_f - \delta_c(7 + 2\delta_f))} \\ & - \frac{(1 + 11\delta_f + 10\delta_f^2 + \delta_c^2(1 + 3\delta_f) - 2\delta_c(1 + 7\delta_f + \delta_f^2))s}{2(1 + \delta_f)(5 + 2\delta_c^2 + 6\delta_f - \delta_c(7 + 2\delta_f))} \\ & + \frac{2(1 - \delta_c)(1 - \delta_c + 2\delta_f)\tau}{5 + 2\delta_c^2 + 6\delta_f - \delta_c(7 + 2\delta_f)}x_t \end{aligned} \quad (2.3.53)$$

$$\begin{aligned} \hat{p}_{nt}^B = & \frac{(\delta_c(4 + 4\delta_f - \delta_f^2) - 2 - \delta_c^2(2 - \delta_f) - 5\delta_f - 3\delta_f^2)\tau}{(1 + \delta_f)(5 + 2\delta_c^2 + 6\delta_f - \delta_c(7 + 2\delta_f))} \\ & + \frac{(1 + 5\delta_f + 5\delta_f^2 + \delta_c^2(2 + 6\delta_f + \delta_f^2))s}{(1 + \delta_f)(5 + 2\delta_c^2 + 6\delta_f - \delta_c(7 + 2\delta_f))} \\ & + \frac{4(1 - \delta_c)(1 - \delta_c + 2\delta_f)\tau}{5 + 2\delta_c^2 + 6\delta_f - \delta_c(7 + 2\delta_f)}x_t \end{aligned} \quad (2.3.54)$$

The boundary  $1 - \tilde{x}_s$  is defined by:

$$1 - \tilde{x}_s = \frac{\tau + s}{4\tau} + \frac{\sqrt{M(M + C^2)} - M}{4tC^2\sqrt{M(M + C^2)}}p_{nt}^B \quad (2.3.55)$$

where  $C$  and  $M$  are defined by (2.3.36) and (2.3.37), respectively.

A similar argument for the existence of an equilibrium when  $x_t \in (0, \min(\tilde{x}_s, \tilde{x}_m))$  applies.

*Proof.* See Appendix. □

The equilibrium described above is valid for a wide range of parameter values, suggesting that for these parameter values next-period market share falls into the no-poaching region. Since the equilibrium price strategies are not straightforward

to interpret, I employ a numerical analysis. It can be shown that when  $x_t$  is close to 1, firm B's introductory price is higher than firm A's price and  $x_{t+1}$  approaches the midpoint on the unit interval from above. On the other hand, when  $x_t$  is farther away from 1, firm B's price is lower than the rival's price, so  $x_{t+1}$  approaches the midpoint of the market from below. This suggests that for  $x_t$  outside the no-poaching region convergence may be non-monotonic.

The lower bound of the region, where B poaches for one period only, is defined as  $\max(1 - \tilde{x}_m, 1 - \tilde{x}_s)$ . Recall that  $1 - \tilde{x}_m$  is the upper limit of the no-poaching region: when  $x_t > 1 - \tilde{x}_m$  firm B has a profitable deviation in poaching while A plays a no-poaching strategy. In addition, when  $x_t \leq 1 - \tilde{x}_s$  firm B has a profitable deviation in not poaching conditional on A not poaching either. If  $1 - \tilde{x}_s \leq 1 - \tilde{x}_m$ , then firm B has no profitable deviation away from  $\hat{p}_{nt}^B$  and Proposition 3 applies to the entire region  $(1 - \tilde{x}_m, 1)$ . By symmetry, similar arguments can be applied towards finding an equilibrium when  $x_t \in (0, \tilde{x}_m)$  and A has a profitable deviation in poaching.

If  $1 - \tilde{x}_s > 1 - \tilde{x}_m$  and  $x_t \geq 1 - \tilde{x}_s$ , then Proposition 3 still applies. If  $1 - \tilde{x}_s > 1 - \tilde{x}_m$  but  $x_t \in (1 - \tilde{x}_m, 1 - \tilde{x}_s)$  there will be no equilibrium in pure strategies. If neither firm poaches, firm B will deviate to a poaching strategy since  $x_t > (1 - \tilde{x}_m)$ . As B adopts the poaching strategy,  $\hat{p}_{nt}^B$ , and A responds by setting  $\hat{p}_{nt}^A$ , B now has a profitable deviation in not poaching since  $x_t < (1 - \tilde{x}_s)$ . A numerical analysis shows that  $(1 - \tilde{x}_m, 1 - \tilde{x}_s)$  is the empty set for a wide range of parameters. For this reason, I do not explore the equilibrium when  $x_t \in (1 - \tilde{x}_m, 1 - \tilde{x}_s)$ .

Recall that the price strategies in Proposition 3 are optimal conditional on

the conjecture that next period the distribution of the market falls within the no-poaching region. For a limited range of the parameter values this conjecture is not correct. In this case we have to solve for the equilibrium strategies by conjecturing that next period the market stays in region 1 - the region where firm B poaches and A does not. If  $x_{t+1}$  falls within  $(1 - \tilde{x}_m, 1 - \tilde{x}_s)$ , then the problem is further complicated by the lack of pure-strategy equilibria for this region. I believe that investigating these scenarios will not contribute substantially to our present discussion so I limit the equilibrium results to the cases described in Propositions 2 and 3.

## 2.4 Discussion

### 2.4.1 Customer Recognition vs. Uniform Pricing

The results regarding the equilibrium with complete lock-in allow us to isolate the impact of customer recognition on profits by comparing my results to those in Beggs and Klemperer (1992) and To (1996). Both papers consider markets characterized by product differentiation, overlapping generations of consumers, infinitely-lived firms, complete customer lock-in due to switching costs and uniform pricing. Beggs and Klemperer assume that consumers have infinite life spans and show that in a symmetric steady state firms charge prices above  $c + \tau$  and generate per-cohort profits exceeding  $\frac{(1+\delta_f)\tau}{2}$ . To (1996) modifies this analysis by considering consumers with finite lifespans and shows that this assumption does not qualitatively alter the level of prices.

My own results from Section 2.3.2 show that per-cohort profits remain below  $(1+\delta_f)\tau/2$  for all  $s$ , which leads us to conclude that steady-state firm profits are lower when sellers can imperfectly price discriminate based on customers purchase history. This result is similar to the one derived in Chen (1997), despite the dissimilar settings (Chen's model is based on homogeneous markets with low switching costs and incomplete lock-in). Unfortunately, we cannot compare the outcomes under incomplete lock-in with their equivalent under uniform prices since there are no models of uniform pricing, product differentiation and low switching costs in the literature yet.

## 2.4.2 Imperfect vs. Perfect Customer Recognition

We can also show that perfect customer recognition (PCR) yields higher profits relative to imperfect customer recognition (ICR). The next section presents the modified model that captures the effect of PCR on prices and profits.

### Perfect Customer Recognition

Let  $p_{nt}$  indicate the price to newcomers,  $p_{st}$  - the price to switchers, and  $p_{ot}$  - the price to loyal customers. Since imperfect customer recognition hampers firms' ability to price discriminate between switchers and newcomers only when switching occurs in equilibrium, I suppose that switching costs are low enough to prevent complete lock-in. The upper bound on  $s$  that allows switching in equilibrium will be determined below. When firms can separate switchers from newcomers, current market share has no impact on  $p_{nt}$ . Therefore, even in the presence of overlapping

generations the firms' problem can be represented through a two-period model where each period firms choose  $p_{st}$  and  $p_{ot}$  on the basis of their current market shares while  $p_{nt}$  is chosen by taking into account expected future profits from the customer base installed today. Let  $t = \{1, 2\}$ , where  $t = 1$  indicates the period when customers are new and  $t = 2$  is the period when customers are in their second period on the market. Let  $x$  stand for firm A's market share captured in period 1. I first consider firm A's problem with respect to  $p_o^A$  and  $p_s^A$  in period 2 where I maintain the assumption that regular prices are set after the rival's offer to switchers is known. Demand from loyal customers can be expressed as

$$q_{AA}(p_o^A, p_s^B) = \min(x_t, \frac{s + \tau + p_s^B - p_o^A}{2\tau}) \quad (2.4.1)$$

so firm A's optimal regular price is

$$p_o^A = \arg \max p_o^A \cdot \min(x_t, \frac{p_s^B + s - p_o^A + \tau}{2\tau}) \quad (2.4.2)$$

$$p_o^A = \max(\frac{p_s^B + s + \tau}{2}, p_s^B + s + 2\tau(\frac{1}{2} - x)) \quad (2.4.3)$$

In turn, firm A's sales to loyal customers are given by:

$$q_{AA} = \frac{\tau + s + P_s^B}{4\tau} \quad (2.4.4)$$

Similarly,

$$p_o^B = \max\left(\frac{p_s^A + s + \tau}{2}, p_s^A + s - 2\tau\left(\frac{1}{2} - x\right)\right) \quad q_{BB} = \frac{\tau + s + P_s^A}{4\tau} \quad (2.4.5)$$

Firm A's demand from switchers in period 2 is given by:

$$q_{BA} = \max\left(0, (1 - x) - \left(1 - \frac{p_o^B + s - p_s^A + \tau}{2\tau}\right)\right) \quad (2.4.6)$$

where  $(1 - x)$  is firm B's market share in period 2 and  $1 - \frac{p_o^B + s - p_s^A + \tau}{2\tau}$  is firm B's mass of loyal customers, conditional on  $p_s^A$ . Assuming  $q_{BA} > 0$  and using  $p_o^B = \frac{p_s^A + s + \tau}{2}$ , firm A's optimal price to switchers is

$$p_s^A = \arg \max p_s^A \cdot \left(\frac{3\tau - p_s^A - s}{4\tau} - x\right) \quad (2.4.7)$$

$$p_s^A = \frac{3\tau - s - 4\tau x}{2} \quad (2.4.8)$$

from which we find that  $q_{BA} = \frac{3\tau - s - 4\tau x}{8\tau}$ .

Similarly, for firm B:

$$p_s^B = \frac{4\tau x - s - \tau}{2} \quad (2.4.9)$$

$$q_{AB} = \frac{4\tau x - s - \tau}{8\tau} \quad (2.4.10)$$

Having found the optimal price to switchers, we can substitute it into the expressions

for  $p_o^i$  and  $q_{ii}$ :

$$\begin{aligned} p_o^A &= \frac{\tau + s + p_s^B}{2} \\ &= \frac{\tau + s + \frac{4\tau x - s - \tau}{2}}{2} \end{aligned} \quad (2.4.11)$$

$$\begin{aligned} &= \frac{\tau + s + 4\tau x}{4} \\ q_{AA} &= \frac{\tau + s + P_s^B}{4\tau} \\ &= \frac{\tau + s + \frac{4\tau x - s - \tau}{2}}{4\tau} \\ &= \frac{\tau + s + 4\tau x}{8\tau} \end{aligned} \quad (2.4.12)$$

$$\begin{aligned} p_o^B &= \frac{\tau + s + \frac{3\tau - s - 4\tau x}{2}}{2} \\ &= \frac{5\tau + s - 4\tau x}{4} \end{aligned} \quad (2.4.13)$$

$$\begin{aligned} q_{BB} &= \frac{\tau + s + \frac{3\tau - s - 4\tau x}{2}}{4\tau} \\ &= \frac{5\tau + s - 4\tau x}{8\tau} \end{aligned} \quad (2.4.14)$$

We can now find the firms' total profits,  $\Pi_2^i$ , from their old customers in period 2 as a function of the beginning-of-the-period market share,  $x$ :

$$\begin{aligned} \Pi_2^A(x) &= \Pi_{switchers}^A + \Pi_{loyal}^A \\ &= \frac{(3\tau - s - 4\tau x)^2}{16\tau} + \frac{(\tau + s + 4\tau x)^2}{32\tau} \end{aligned} \quad (2.4.15)$$

$$\begin{aligned} \Pi_2^B(x) &= \Pi_{switchers}^B + \Pi_{loyal}^B \\ &= \frac{(4\tau x - \tau - s)^2}{16\tau} + \frac{(5\tau + s - 4\tau x)^2}{32\tau} \end{aligned} \quad (2.4.16)$$

In period 1 firm A sets  $p_n^A$  in order to maximize the present value of profits

per cohort entering in period 1. The marginal newcomer will purchase from A if

$$\begin{aligned}
p_n^A + \tau x + \delta_c \min(p_o^A + \tau x, p_s^B + \tau(1-x) + s) & \quad (2.4.17) \\
\leq p_n^B + \tau(1-x) + \delta_c \min(p_o^B + \tau(1-x), p_s^A + \tau x + s)
\end{aligned}$$

Using (2.4.8) and (2.4.9), firm A's demand from newcomers can be expressed as

$$q_{1A} = x = \frac{p_n^B - p_n^A + \tau(1 + \delta_c)}{2\tau(1 + \delta_c)} \quad (2.4.18)$$

Note that under PCR demand from newcomers becomes less elastic as consumers become more patient. The firms' optimal introductory price to newcomers are determined simultaneously and are given by:

$$p_n^A = \arg \max p_n^A \cdot \frac{p_n^B - p_n^A + \tau(1 + \delta_c)}{2\tau(1 + \delta_c)} + \delta_f \Pi_2^A(x) \quad (2.4.19)$$

$$p_n^B = \arg \max p_n^B \cdot \left(1 - \frac{p_n^B - p_n^A + \tau(1 + \delta_c)}{2\tau(1 + \delta_c)}\right) + \delta_f \Pi_2^B(x) \quad (2.4.20)$$



This produces the following solution:

$$p_n^A = p_n^B = \left(1 + \delta_c - \frac{\delta_f}{4}\right) \tau - \frac{3}{4} \delta_f s \quad (2.4.21)$$

$$x = 1/2 \quad (2.4.22)$$

$$p_s^A = p_s^B = \frac{\tau - s}{2} \quad (2.4.23)$$

$$q_{BA} = q_{AB} = \frac{\tau - s}{8\tau} > 0 \quad \forall s < \tau \quad (2.4.24)$$

$$p_o^A = p_o^B = \frac{3\tau + s}{4} \quad (2.4.25)$$

$$q_{AA} = q_{BB} = \frac{3\tau + s}{8\tau} \quad (2.4.26)$$

$$(2.4.27)$$

First, the results above show that under PPD the price to new customers again does not fall below cost (here normalized to zero) for the admissible range of  $s$ , i.e.  $s < \tau$ . Second,  $p_n$  decreases in the firm discount factor (because firms place higher value on profits from market share tomorrow) and increases in consumer patience (because we showed consumers become less price sensitive as they grow more patient). The newcomers' price also decreases in the switching costs and  $\partial p_n / \partial s$  only depends on the firm discount factor – from  $x(p_n^A, p_n^B)$  we saw that consumers will incur  $s$  as a cost either by switching or by paying at least that much more if they stay, so the consumer discount factor is irrelevant; on the other hand, firms anticipate that their profits from loyal customers are increasing in  $s$  and the more they value these profits the more they are willing to lower the price to newcomers today in order to capture market share. Note also that switching costs

must be below  $\tau$  for switching to occur in equilibrium.

Naturally, the optimal price to switchers is below the price to loyal customers, i.e.  $p_s < p_o$ . What remains to be determined is how the price to newcomers relates to  $p_s$  and  $p_o$ . Comparing  $p_n$  to  $p_o$ , we find that lower introductory offers emerge, i.e.  $p_n < p_o$ , if and only if switching costs are sufficiently high:

$$p_n < p_o \Leftrightarrow s > \frac{4\delta_c + 1 - \delta_f}{1 + 3\delta_f} \tau \quad (2.4.28)$$

We can further verify that the above condition will be satisfied for some range of values in  $s \in [0, \tau)$  if  $\delta_c < \delta_f$ , because the latter condition ensures that  $\frac{4\delta_c + 1 - \delta_f}{1 + 3\delta_f} \tau$  is less than  $\tau$ , the upper bound on switching costs in the model. On the other hand, if  $\delta_c \geq \delta_f$  or  $s \leq \frac{4\delta_c + 1 - \delta_f}{1 + 3\delta_f} \tau$ , we find that loyal customers are offered a loyalty discount:  $p_o \leq p_n$ . This occurs because low  $s$  makes switching more attractive and firms are induced to charge lower prices to loyal customers. This, in turn, reduces the payoff from market share and relaxes competition for new customers, resulting in higher introductory prices.

Since  $p_o > p_s$ , having low switching costs results in  $p_n > p_o$ , which leads to  $p_n > p_o > p_s$  – switchers pay the lowest price, followed by loyal customers who are offered a discount, and finally new customers pay the highest price. Hence, low switching costs and perfect customer recognition lead to endogenous loyalty discounts. If switching costs are high ( $s > \frac{4\delta_c + 1 - \delta_f}{1 + 3\delta_f} \tau$ ) and firms are sufficiently patient ( $\delta_f > \delta_c$ ), then new customers still receive a discount relative to loyal customers as in the ICR case. Furthermore, if  $s > \frac{4\delta_c + 2 - \delta_f}{2 + 3\delta_f} \tau$  (a condition stronger than  $s > \frac{4\delta_c + 1 - \delta_f}{1 + 3\delta_f} \tau$ ) we

also obtain that  $p_n < p_s$  – i.e., for very high levels of  $s$ , newcomers are charged a lower price than switchers because market share becomes more attractive while sales to switchers become less profitable.

The equilibrium profits per cohort can also be shown to be higher under PCR relative to ICR. Under PCR, the profit per cohort equals

$$\begin{aligned}\Pi_{PCR} &= \frac{1}{2} \cdot \left( (1 + \delta_c - \frac{\delta_f}{4})\tau - \frac{3}{4}\delta_f s \right) + \delta_f \left( \frac{(3\tau - s - 4\tau(1/2))^2}{16\tau} + \frac{(\tau + s + 4\tau(1/2))^2}{32\tau} \right) \\ &= \frac{1 + \delta_c - \delta_f}{2}\tau + \frac{3}{8}\delta_f(\tau - s) + \delta_f \left( \frac{(\tau - s)^2}{16\tau} + \frac{(3\tau + s)^2}{32\tau} \right)\end{aligned}\tag{2.4.29}$$

We can write:

$$\begin{aligned}\Pi_{PCR} - \Pi_{ICR} &= \frac{1 + \delta_c - \delta_f}{2}\tau + \frac{3}{8}\delta_f(\tau - s) + \delta_f \left( \frac{(\tau - s)^2}{16\tau} + \frac{(3\tau + s)^2}{32\tau} \right) - \delta_f \frac{(\tau + s)^2}{8\tau} \\ &= \tau^2(16 + 16\delta_c + 2\delta_f) + 6\delta_f s^2 + \delta_f(\tau - s)^2 \\ &> 0\end{aligned}\tag{2.4.30}$$

The comparison above suggests that firms would be better off if they could distinguish switchers from newcomers. This result may explain why some stores carrying product lines from multiple suppliers issue coupons for the rival's product at the point of sale. The widespread implementation of bonus cards in grocery and convenience stores could be motivated by the stores' willingness to uniquely identify customers and trace their purchase patterns as this facilitates perfect customer

recognition at the supplier level and increases industry profits.

## 2.5 Conclusion

In this paper I present an analysis that integrates imperfect customer recognition and consumer switching costs in the context of dynamic competition in a differentiated-goods duopoly. The model presented here builds upon Villas-Boas (1999) and complements the study of dynamic competition with switching costs by introducing customer recognition. This allows us to incorporate the switching cost explicitly in the demand functions and derive closed-form solutions for the equilibrium prices, which enables a comparative statics analysis.

There are two sets of market equilibria depending on the level of the switching cost. For all values of the switching cost, customer recognition gives rise to a ‘bargain-then-ripoff’ pattern in prices – this feature would be present even if switching costs were zero and is due to firms’ ability to price discriminate between new and repeat customers. When switching costs are low enough to allow customer switching in equilibrium, they only amplify the loyalty price premium and increase firms profits. The price to new customers does not fall below cost because firms keep only a fraction of their equilibrium market share as loyal customers. Switching costs do not affect the speed of convergence to steady state. When consumers are very patient, demand from newcomers is perfectly elastic and convergence to steady state occurs in just one period.

When switching costs are high, there can be complete customer lock-in, such

that neither firm is able to ‘poach’ the rival’s customers. Firm profits are independent of switching costs because any discounts that are conditional on the size of the switching costs are extracted from the captured consumers in the form of loyalty premiums when in their second period in the market. Because firms compete for more than half of the market, introductory prices may fall below cost. Under complete customer lock-in, convergence to steady state occurs in just one period when the current distribution of the market is such that both firms find it optimal to retain all of their previous customers.

The model also suggests that imperfect customer recognition leads to lower profits relative to both uniform pricing and perfect customer recognition. If firms can distinguish new, unattached consumers from switchers, they can increase their profits by price discriminating between these two types. Under such perfect customer recognition, loyalty discounts would emerge if switching costs are sufficiently low; otherwise, newcomers will be offered introductory offers, which are below the price paid by loyal customers.

## **Chapter 3**

# **Inter-Firm Information Sharing, Competition, and Liquidity Constraints: Theory with Evidence from Madagascar**

### **3.1 Introduction**

In the absence of adequate legal protection against contract breach, firms can reduce their exposure to contractual risk in one-shot transactions by exchanging information about defectors. The goal of this paper is to investigate whether competition discourages such exchange. Previous studies that analyze information sharing in a competitive environment have focused exclusively on lending institutions and on

the impact that pooling information on borrowers' histories has on lenders' market power over their customers. In contrast, I look at this issue from the perspective of firms and consider firms' exposure to risk from trade partners in both the upstream and downstream markets. Furthermore, I propose a new channel through which competition may deter information exchange among rivals. Foreseeing that sharing information reduces the rival's exposure to such risk, a firm holding private information about a defector may have an incentive not to reveal this information depending on how much it can benefit from exposing its rival to higher risk of default. Hence, information sharing agreements may not be sustained among rivals. This approach gives rise to two novel theoretical insights: i) in imperfect credit markets liquidity plays a key role in facilitating the exchange of information between rivals; ii) information sharing may be easier to sustain in ex-ante more competitive markets. I test the model's predictions using a unique firm-level dataset on the information sharing practices of agricultural traders in Madagascar.<sup>1</sup> I find strong support for the predicted positive impact of liquidity on information sharing and establish that traders who report stronger competition in their markets are more likely to share information.

The main premise of my model is that suffering contract breach can translate into an unanticipated cash outflow that weakens the firm's ability to compete depending on its liquidity position. When a customer defaults on a payment or a supplier does not deliver goods on time, the firm has to employ additional resources

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<sup>1</sup>The dataset comes from a survey conducted by the International Food Policy Research Institute and the Malagasy Ministry of Scientific Research. I am grateful to Marcel Fafchamps and Bart Minten for sharing this dataset with me.

in order to meet its own payment or delivery obligations. Some firms may anticipate an average rate of default in their operations and hold precautionary capital or inventory.<sup>2</sup> However, when a higher than the expected rate of default occurs and the firm does not have sufficient resources, it has to borrow money to maintain the firm's operations - the cost of securing short-term capital will temporarily raise the firm's marginal cost. Hence, an episode of contract breach can be viewed as a transitory adverse cost shock to the firm that was cheated. Depending on how much the rival firm can benefit from the resulting cost advantage, it may have an incentive to expose the other firm to a higher risk of default and profit from its vulnerability.<sup>3</sup>

I refer to firms with low cost of funds as 'liquid' – for these firms the experience of contract breach will have minimal impact on their marginal cost and, hence, on their rival's profitability. As a result, the rival has a weaker incentive to withhold information and expose the firm to higher default risk. Alternatively, 'liquidity constrained' firms face a high cost of funds and upon experiencing above average rates of default, the shock to their marginal cost is larger. As a result, liquidity constrained firms are more vulnerable to the risk of default and their rivals can realize higher profits by withholding information. The key insight here is that the detrimental impact of competition on information sharing depends on the liquidity positions of the firms in a given market.

I model information sharing as the Pareto-optimal non-cooperative equilibrium

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<sup>2</sup>See Fafchamps et al. (2000) for empirical evidence on Zimbabwean firms' holdings of precautionary inventory stocks in the face of high contract risk.

<sup>3</sup>This reasoning is somewhat similar to the 'deep pockets' concept in the predatory pricing literature (McGee, 1958; Telser, 1966; Bolton and Scharfstein, 1990) although in our case, it is only the deep pockets of the rival that matter.



of the information-sharing supergame between two rival firms (Friedman, 1971). Firms use grim trigger strategies and punish rivals, who do not reciprocate in the information exchange, by not revealing information in the future. The strategic cost of information sharing determines the short-term incentive to deviate from the cooperative strategy of sharing information and is given by the additional profits a firm can realize when it withholds information and exposes the rival to higher risk of default. On the other hand, playing the cooperative strategy gives rise to long-term benefits arising from lower exposure to contractual risk for both firms. The main finding of the model is that information sharing can be sustained at lower firm discount factors when firms are liquid, because the temptation to deviate is lower when a firm's rival faces a low cost of funds. Furthermore, if we assume that firms within a market are either both liquid, or are both liquidity constrained, then we can formulate the testable prediction that information sharing is more likely to be observed among liquid firms.

I next examine the intuitive claim that more intense competition would provide stronger disincentives to information sharing. I employ a market framework, in which competition intensity varies along three dimensions - product differentiation, switching costs, and consumer patience. For tractability, I limit attention to markets in which consumers are very patient (consumers live two periods only) and characterize the profits that a firm will forgo when it reveals information about a defector to its rival - these profits comprise the strategic cost of information sharing. I show that this cost is zero when the rival's cost of funds is sufficiently low - i.e. when it is below an endogenously determined liquidity threshold. This threshold depends

on the the level of product differentiation and the magnitude of the switching costs, which allows for a comparative statics exercise.

The effect of competition intensity is ambiguous and depends on the underlying market features. When driven by lower switching costs or lower degree of product differentiation, more intense competition lowers the liquidity threshold and on average raises the strategic cost of information sharing. However, consumer patience is also shown to play a role. The model exhibits the feature that the market becomes more competitive as consumers become more patient. I show that the strategic cost of information sharing is zero when consumers are infinitely patient. I also provide an intuitive discussion for the case where consumers are not infinitely patient, which illustrates that the strategic cost of information sharing is likely to be positive in less competitive markets when the degree of competition is varied along the degree of consumer patience. Previous studies of competition and information sharing have placed little emphasis on the features of the competitive environment.<sup>4</sup> Furthermore, the approach in these studies is to analyze how information sharing affects competition and the the desirability of an information-sharing regime then depends on the change in the competitive environment and its implications for the banks' profitability. This study contributes to the literature by presenting a more detailed picture of the various market parameters through which competition affects information sharing behavior rather than vice versa.

I use survey data from Madagascar to test the model's predictions regarding

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<sup>4</sup>In Jappelli and Pagano (1993) the exogenous level of competition is proxied by the cost advantage of the incumbent bank relative to a potential entrant, while in Gehrig and Stenbacka (2006) it is proxied by the dispersion of switching costs that borrowers incur when changing lenders.

the impacts of liquidity and competition intensity on information sharing practices. The data does not allow the identification of a trader's rivals. However, assuming that traders within a market have similar liquidity positions such that a trader's liquidity position is a proxy for the position of its rival, the model suggests that more liquid firms would be more likely to share information because they are also facing more liquid rivals. Consistent with this hypothesis, I find that firms operating in liquid markets are significantly more likely to share information about delinquent customers. The results are qualitatively equivalent under two alternative measures of liquidity – access to informal credit and availability of own liquid funds, – and robust to the inclusion of a rich set of controls. One of the liquidity measures is credibly exogenous, so its coefficient can be interpreted as a causal estimate of the positive effect of liquidity on information sharing.

Next, I find a positive and statistically significant relationship between the intensity of competition, as reported by the trader, and information sharing. Unfortunately, a lack of suitable instruments prevents me from establishing a statistically significant causal relationship. However, to the best of my knowledge, this study is the first to present empirical evidence on the correlation between competition intensity and information sharing practices based on observational data.<sup>5</sup>

The rest of the paper is organized as follows. Section 2 presents the theoretical model that links the strategic cost of information sharing to the rival's cost of funds and discusses firms' incentives to share information. Section 3 describes the data

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<sup>5</sup>Brown and Zehnder (2008) present experimental evidence on this relationship in a credit market environment and find that stronger competition reduces information sharing. Their experimental design follows Pagano and Jappelli (1993) who theoretically explore the effects of competition and adverse selection on the incentives of competing lenders to pool information.

and the empirical strategy. Section 4 presents the results and Section 5 concludes.

## 3.2 Theoretical Model

### 3.2.1 Preliminaries

I consider the sustainability of a self-enforcing information-sharing agreement between two rival firms. The firms may agree to share timely information about defectors but their agreement cannot be enforced in court. In the one-shot non-cooperative game, sharing information about defectors will be shown to be a weakly dominated strategy. However, information sharing can be sustained as the Pareto-optimal, non-cooperative equilibrium of the infinitely-repeated stage game. Information-sharing practices in credit markets are often based on reciprocity. For example, members in credit bureaus have an obligation to report information and, in turn, can access credit reports at a much lower cost than non-members (Klein, 1992). Case study evidence on informal information sharing arrangements suggests that firms report defectors to other firms in the market in expectation that the favor will be returned (Vinogradova, 2006).<sup>6</sup>

Firms have an incentive to participate in information-sharing networks because they reduce their exposure to contractual risk. First, information sharing networks within a market allow firms to screen out defectors if history of past default is any indication of future propensity to cheat. Second, the existence of such networks

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<sup>6</sup>In a detailed account of the information networks among small business owners in Russia, Vinogradova (2006) reports that one business owner explicitly states that other firms share information with him because they expect this favor to be reciprocated in the future.

may have a disciplinary effect that reduces the fraction of cheaters in the population (Padilla and Pagano, 2000; Jappelli and Pagano, 2002). On the other hand, while firms may ex ante agree to share information, such commitment is credible ex post only if the costs of disclosing information today do not exceed the net benefits of reduced exposure to risk in the future. The main contribution of this paper is to illustrate how liquidity can affect the cost of disclosing information to a rival and, hence, on the viability of information-sharing practices.

The sequence of events is summarized in Figure 3.1. In some initial period  $t_0$  firms declare their intent to share information; the ensuing obligation is not enforceable by courts or other third parties, so even though we use the term ‘agreement’ it should be noted that this agreement is non-binding. At the beginning of each subsequent period firms simultaneously choose whether to disclose their private information or not; afterwards they sign contracts with agents (i.e. customers, suppliers or other trade partners), a fraction of whom have unilateral incentive to breach their contracts with the firm. Firms do not sign contracts with agents who are known to have defaulted in the past (defectors). Not revealing private information about the identity of defectors is equivalent to deviating from the information sharing agreement. Deviations in the current period are discovered at the end of that period – firms are assumed to be able to verify if the information transmitted by their rival at the beginning of the period reflected the full scope of the information the rival possessed at the time. Also at the end of the period, firms discover the aggregate default rate for the period.

Naturally, a discussion of the emergence of an information sharing regime is

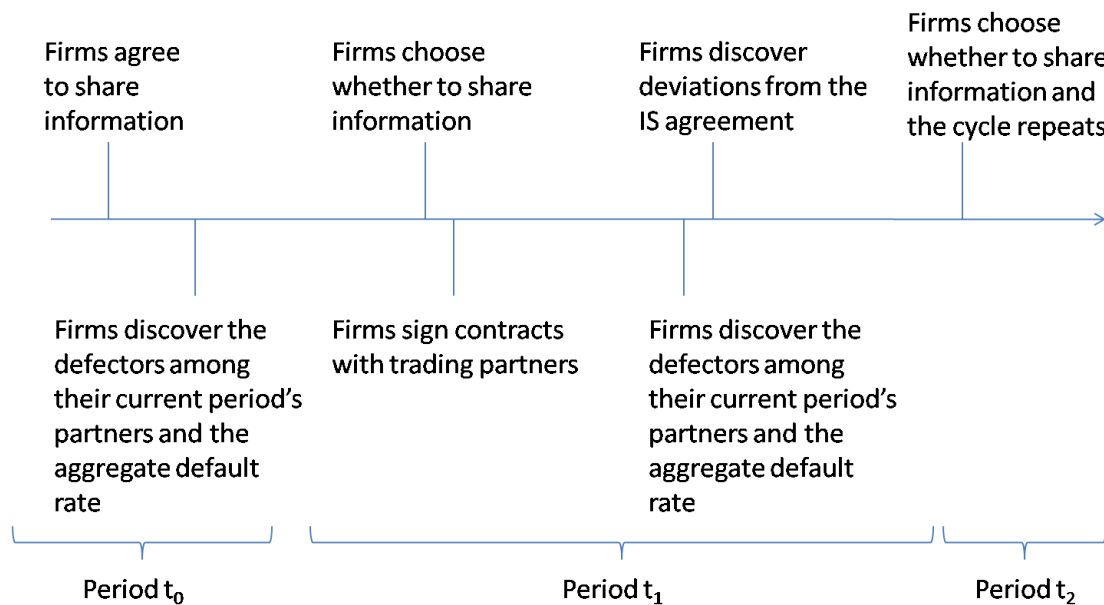


Figure 3.1: Timeline of events.

warranted to the extent that it benefits firms by reducing their exposure to contractual risk.<sup>7</sup> Hence, I presume that i) in the absence of competition firms have incentives to share information ex-post (e.g. the benefits from information sharing outweigh the physical cost of information transmission) and that there are no other feasible and possibly cheaper means of enforcing contracts (e.g. engaging in long-term bilateral relations or resorting to third parties to enforce contracts); and ii) there is a time lag between two cheating incidents by the same agent so that the exchange of information can have any value.

Sharing information is assumed to be a game of complete information in the sense that deviations from the cooperative strategy are detected perfectly and with no lag. Failing to report on the identity of a defector or falsely reporting honest

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<sup>7</sup>The magnitude of these benefits may depend on the number of firms pooling information, the share of dishonest agents in the population, the share of agents who are deterred from cheating by the knowledge that their actions will be public knowledge, and the magnitude of the contractual losses being avoided. I assume that these factors are held constant throughout the analysis.

agents as defectors is considered to be a deviation from the information-sharing strategy. These assumptions are consistent with the theoretical setting in Kandori (1992) and Okuno-Fujiwara and Postlewaite (1995), whose insights we use to motivate information sharing as a feasible device that facilitates the emergence of reputation mechanisms in games of random matching. They are needed to avoid the plethora of issues related to truth-telling in repeated games where the actions of agents are observed by only a subset of the population.<sup>8</sup> Within this context, Annen (2007) tackles truthful information sharing and shows that truth-telling can be obtained as a unique dominant strategy equilibrium.<sup>9</sup> He also points out that this equilibrium is harder to sustain among competing players who have an incentive to slander each other because slandering triggers a punishment on the opponent. This result suggests that truth-telling may be a serious issue in information sharing if firms can benefit from misreporting the performance on honest agents. At this point, it is assumed in our model that firms report information truthfully.

Firms start each period with the expectation that some fraction of their trade partners will cheat. Contract breach can take many forms - for example, customers may cheat by not repaying their credit or by pre-ordering goods that they do not purchase later; similarly, suppliers may cheat by not delivering the contracted goods on time or by delivering goods of lower quality. Such incidents can cause a disruption to the cheated firm's expected stream of cash and inventory flows. To cope with this disruption, the firm can either seek additional funds, internally through retained

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<sup>8</sup>See Ben-Porath and Kahneman (1996 and 2003), and Anderlini and Lagunoff (2005).

<sup>9</sup>This equilibrium does not satisfy the assumption in Kandori (1992) and Okuno-Fujiwara and Postlewaite (1995) that players only need to communicate 'simple' information in the form of labels.

earnings or externally through borrowing, or it can rely on excess inventory whenever available. I do not distinguish between a firm borrowing capital or negotiating the delivery of goods on credit as they both serve the same purpose of supporting the firm's operations.<sup>10</sup> Either alternative is costly and the additional costs of securing additional inventory or cash holdings add up to the marginal cost of operation in the next period.

Originally, firms are assumed to be symmetric in their average default rate but informational asymmetries, arising from one firm sharing information while the other one does not, give rise to asymmetric exposure to risk and asymmetric marginal costs of operation in the next period. The firm that is exposed to a higher average rate of default (e.g. because its rival deliberately did not disclose information) has to incur higher costs of maintaining its operations in the next period. Hence, a higher risk of default for one of the firms in the market can be interpreted as causing an adverse cost shock to that firm in the following period.

All else equal, the magnitude of the cost shock will be increasing in the firm's cost of funds. Naturally, the cost shock will be smaller for a firm that relies on retained earnings or has cheap access to trade credit relative to a firm that borrows from a moneylender. Hence, I refer to firms with a low cost of securing liquid assets (such as cash and inventory) as liquid; firms for which these costs are high will be referred to as liquidity-constrained. While I recognize that a firm may be unable to borrow at times of need and face capacity constraints, I do not explicitly model

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<sup>10</sup>Fafchamps et al (2000) propose that excess inventory holdings may be motivated by the desire to insure against contractual risk and find evidence of this motive in their data on Zimbabwean export firms who are particularly prone to contract risk from overseas partners.



this possibility as it entails analyzing a Bertrand-Edgeworth version of the dynamic model described below with potentially no pure-strategy equilibria.<sup>11</sup> Therefore, the case where a firm in reality experience binding capacity constraints due to contract breach can be modeled as a very high cost of funds.

A firm’s decision to share information has a direct effect on the probability that its rival experiences a higher than anticipated rate of cheating. If a firm can derive sufficiently high benefits from the rival’s higher exposure to risk, then it will have incentives to deviate from the information sharing agreement by withholding information. To fix ideas, consider the stage game in Figure 3.2. Firms can take two actions: they can reveal information (*‘Share’*) or they can withhold information (*‘Do not share’*).

Figure 3.2: The information-sharing stage game.

		Firm B	
		Do not share	Share
Firm A	Do not share	$k, k$	$m, l$
	Share	$l, m$	$n, n$

The parameters,  $k, l, m$  and  $n$ , that can describe the one-shot information sharing game are as follows. It is assumed that firms benefit from receiving information about defectors because it reduces their exposure to contractual risk:  $n > k$  and  $m > k$ .<sup>12</sup> However, unilaterally revealing information is costly not only because the firm does not lower its exposure to risk (since it does not receive information

<sup>11</sup>For characterization of the equilibria in a one-period model of Bertrand-Edgeworth competition with product differentiation, see Boccard and Wauthy (2005).

<sup>12</sup>Note that  $n$ , the firms’ payoff when they both share information, can be adjusted to absorb the physical cost of information transmission and it is assume that this cost is sufficiently small to make information sharing desirable in the absence of competition.

from its rival) but also because its risk of default is now higher relative to that of its rival; hence,  $l < k$ . The assumption that we challenge in this paper is that in a competitive environment  $m > n$  – firms are better off when they receive information from their rival but do not return the favor. One of our main goals is to identify conditions under which  $m = n$ . Note that if  $m > n$ , the only Nash equilibrium of the stage game is *(Do Not Share, Do Not Share)* information sharing can only be sustained if firms are sufficiently patient. However, if  $m = n$ , there are two Nash Equilibria – *(Do Not Share, Do Not Share)* and the Pareto-optimal *(Share, Share)*, – and information sharing becomes a question of coordinating on the latter or it can be sustained under minimal requirements on the firms’ discount factors.

Based on the asymmetry in the firms’ exposure to risk when one of them withholds information, the model will explore to what extent that firm can benefit from this deviation. Such benefits will arise from the competitive advantage that the deviating firm obtains when it exposes its rival to a higher risk of default. The key finding of the model will show that for a given firm  $m = n$  when the firm’s rival is sufficiently liquid and  $m > n$  if the rival is liquidity constrained. The natural corollary of this result is that an information sharing agreement is more easily sustained among liquid firms than it is among firms that are liquidity-constrained as the latter have a strictly positive incentive to deviate; the liquid firms have no incentive to deviate at all.

I illustrate firms’ strategic motives to withhold information by using a dynamic model of imperfect competition featuring infinitely-lived firms and overlapping generations of consumers. While a simpler static model would be sufficient to illustrate

how liquidity can affect firms' incentives to share information, the dynamic model I develop can additionally shed light on the complex ways in which competition intensity can affect information sharing incentives. I begin by characterizing the steady-state equilibrium of the market when the firms have symmetric cost structures. This implies that they also have symmetric average probabilities of experiencing contract breach from agents. Next, I re-examine the market equilibrium when one firm is exposed to relatively higher probability of contract breach during a single period – this is equivalent to the experience of a transitory cost shock that affects a single firm only. If a firm realizes higher profits when its rival is hit by such shock, then the additional profits would constitute the firm's strategic cost of information sharing as revealing information about defectors reduces the probability that the firm will realize these profits. In terms of the notation in Figure 3.2 the strategic cost of information sharing will be captured by the difference  $m - n$ . Finally, I discuss how the cost of funds affects firms' incentives to share information, perform comparative statics with respect to the competition parameters and formulate testable hypotheses.

### **3.2.2 The market**

This section characterizes the market and its equilibrium properties when there is no uncertainty regarding the firm's next period costs. I will discuss how relaxing this assumption affects the market equilibrium in Section 3.2.3. The model of market competition that I introduce below possesses a number of features that make

it particularly suitable for our analysis and justify the level of sophistication and the limitations that come with it. First, I use a duopoly model because the potential benefits from a firm's distress accrue to a single rival and the incentive to withhold information, if any, is strongest.<sup>13</sup> Second, the model has features, such as product differentiation, consumer switching costs and consumer patience, that provide exogenous variation in the intensity of competition and allow us to investigate how ex ante more intense competition affects information sharing, based on different competition parameters. Third, I introduce imperfect customer recognition – firms distinguish between new customers and repeat customers but cannot distinguish a newcomer from a switcher. Customer recognition is exogenous and further intensifies the competition for market share. It also makes the model more tractable as it allows us to derive intuitive closed-form solutions for the equilibrium prices.<sup>14</sup> It is also important to note that aside from their impact on competition, customer recognition and consumer switching costs are two features that add more realism to the model as they are both commonly found in markets characterized by relational contracting and weak rule of law.<sup>15</sup> Fourth, by assuming that firms are infinitely-lived, face overlapping generations of customers and consumers incur switching costs, I allow firm profits to be path dependent. This captures the possi-

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<sup>13</sup>Greif (2006, pg. 446) notes that in 'thick' markets the cost of providing information could be negligible but this would not be the case in 'thin' markets where firms may be unwilling to help their rivals.

<sup>14</sup>For a discussion of the role of customer recognition on prices in dynamic models of product differentiation and switching costs, see Grozeva (2009). For a comparable model without customer recognition and assuming complete customer lock-in, see Beggs and Klemperer (1992) and To (1996).

<sup>15</sup>Numerous case studies document that in relation-based market interaction, customer recognition and switching costs arise as firms prefer to deal with their established partners even if this entails forgoing better deals from new partners (McMillan and Woodruff, 1999; Vinogradova, 2006).

bility that a transitory adverse cost shock may affect the future stream of profits of both firms, thus amplifying the shock's effect.

I consider a duopoly market consisting of two infinitely-lived firms,  $i = \{A, B\}$ , selling a nondurable good. Consumers have uniformly distributed preferences over the products of the two firms, which gives rise to ex-ante product differentiation. The degree of product differentiation is exogenously determined and fixed. Each firm produces the good at a constant marginal cost,  $c$ . Consumers enter the market for two periods only and demand one unit of the good in each period. They have common valuation for the good given by  $v$ , which I assume to be sufficiently high to induce a purchase in every period. Each period an old cohort of consumers exits the market and a new cohort of equal size enters. In any given period, a firm faces two overlapping generations of consumers: old consumers in their second period in the market who have established a purchase history; and newcomers, who enter the market in the current period and have not purchased from either firm yet. If customers purchase from the same supplier in both periods they are referred to as 'loyal' customers, while if they purchase from two different suppliers over their lifetime, they are referred to as 'switchers'. Firms recognize their own loyal customers but cannot determine if a new customer is a newcomer with no purchase history or a switcher from the rival firm.<sup>16</sup>

Using Hotelling's framework to model product differentiation, suppose that firms are located at the opposite ends of the unit interval with firm A located at

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<sup>16</sup>This setup is an extension of the model of dynamic competition developed in Villas-Boas (1999). The main difference lies in the fact that I include switching costs in the analysis, which enables us to extend the analysis to markets with complete customer lock-in. See Grozeva (2009) for a detailed exposition of the equilibria under incomplete and complete customer lock-in.

0 and firm B – at 1. Each cohort of customers has mass normalized to one and consumers are uniformly distributed over the unit interval. Consumer preferences, as proxied by location on the unit interval, are time-invariant and known to the consumer ex ante. I stipulate that customers face a linear transportation cost of  $\tau$  per unit of distance, so a consumer located at  $x$  will incur transportation costs of  $\tau x$  if she buys from A, or  $\tau(1 - x)$  if she buys from firm B. A consumer who switches suppliers in her second period also incurs a switching cost,  $s$ , which is assumed to be time-invariant, uniform across consumers and common knowledge. All new customers (i.e. newcomers and switchers) are offered an *introductory* price,  $p_{nt}^i$ , where the superscript  $i$  indicates the firm, the subscript  $t$  indicates the time period and the subscript  $n$  indicates that this is the price offered to new customers. Loyal customers are offered a *regular* price,  $p_{ot}^i$ , where the notation is similar except that the subscript  $o$  indicates that this is the price to old customers. Firms simultaneously announce their introductory prices at the beginning of each period but each firm sets its regular price only after observing the introductory price of the rival. This assumption guarantees the existence of a pure-strategy equilibrium in periods when the distribution of market share is very unequal.<sup>17</sup>

Let  $q_{ii,t}$  indicate demand from firm  $i$ 's loyal customers in period  $t$ ,  $q_{ij,t}$  – demand from old customers who switch from  $i$  to  $j$ ,  $j = \{A, B\}$ , in period  $t$ , and  $q_{1i,t}$  – demand from newcomers at time  $t$  who purchase from  $i$  in their first period in the market. Initially, I suppose that marginal costs are constant, symmetric and equal

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<sup>17</sup>This is a common assumption in models of customer recognition where customers are heterogeneous in some characteristic: Villas-Boas (1999) applies it to firms, and Marquez (2002) applies it to banks.

to  $c \geq 0$ . I start by characterizing the demand functions for each of the three groups of customers: newcomers, switchers and loyal customers. Then, I present the steady-state equilibrium of the market and discuss the market dynamics.

### Demand from newcomers

To derive each firm's demand from newcomers, I first determine the location of the marginal consumer among newcomers in the market. This location also determines the distribution of the market in the current period and the market shares that firms will inherit in the following period. I indicate the location of the marginal consumer among newcomers at time  $t$  as  $x_{t+1}$ , where  $x_{t+1}$  will also stand for firm A's market share in period  $t + 1$ . Indicate the consumer discount factor as  $\delta_c$  where  $\delta_c \in (0, 1]$ . Assuming that consumers have perfect foresight, a newcomer located at  $x$  will purchase from firm A in her first period in the market if this purchase renders a weakly higher surplus than purchasing from firm B over the consumer's two-period life span in the market:

$$\begin{aligned} v - p_{nt}^A - \tau x + \delta_c \max(v - p_{ot+1}^A - \tau x, v - p_{nt+1}^B - s - \tau(1 - x)) & \quad (3.2.1) \\ \geq v - p_{nt}^B - \tau(1 - x) + \delta_c \max(v - p_{ot+1}^B - \tau(1 - x), v - p_{nt+1}^A - s - \tau x) \end{aligned}$$

The marginal newcomer, located at  $x_{t+1}$ , will be just indifferent between the

two sequences of purchases when

$$\begin{aligned}
p_{nt}^A + \tau x_{t+1} + \delta_c \min (p_{ot+1}^A + \tau x_{t+1}, p_{nt+1}^B + s + \tau(1 - x_{t+1})) & \quad (3.2.2) \\
= p_{nt}^B + \tau(1 - x_{t+1}) + \delta_c \min (p_{ot+1}^B + \tau(1 - x_{t+1}), p_{nt+1}^A + s + \tau x_{t+1})
\end{aligned}$$

Since it is assumed that the regular price is set after the rival's introductory price is known, firm A will always set  $p_{ot+1}^A$  such that its marginal loyal customer at time  $t + 1$  is just indifferent between switching and staying after having purchased from A at time  $t$ . If firm A wants to keep all of its customers in period  $t + 1$ , it will set  $p_{ot+1}^A + \tau x_{t+1} = p_{nt+1}^B + s + \tau(1 - x_{t+1})$ . If it wants to let some customers switch, then for firm A's marginal customer located at  $x_{t+1}$  it must be true that  $p_{ot+1}^A + \tau x_{t+1} > p_{nt+1}^B + s + \tau(1 - x_{t+1})$ . In either case, we have

$$\min (p_{ot+1}^A + \tau x_{t+1}, p_{nt+1}^B + s + \tau(1 - x_{t+1})) = p_{nt+1}^B + s + \tau(1 - x_{t+1}) \quad (3.2.3)$$

Otherwise, firm A can always increase its profits by raising  $p_{ot+1}^A$  without affecting demand from loyal customers. Therefore, the location of the marginal newcomer at time  $t$  can be determined from:

$$\begin{aligned}
p_{nt}^A + \tau x_{t+1} + \delta_c (p_{nt+1}^B + s + \tau(1 - x_{t+1})) & \quad (3.2.4) \\
= p_{nt}^B + \tau(1 - x_{t+1}) + \delta_c (p_{nt+1}^A + s + \tau x_{t+1})
\end{aligned}$$



This equality also determines the distribution of market share at the beginning of period  $t + 1$ :

$$x_{t+1} = \frac{\tau(1 - \delta_c) + \delta_c(p_{nt+1}^A - p_{nt+1}^B) + p_{nt}^B - p_{nt}^A}{2\tau(1 - \delta_c)} \quad (3.2.5)$$

Demand from newcomers can be defined as:

$$q_{1A,t} = x_{t+1}, \quad \text{and} \quad q_{1B,t} = 1 - x_{t+1} \quad (3.2.6)$$

### Demand from loyal customers

The marginal loyal customer for firm A at time  $t$  will be just indifferent between switching and staying. Therefore, her location,  $x_t^l$  can be determined from the equality of the payoffs of each alternative:

$$p_{ot}^A + \tau x_t^l = p_{nt}^B + s + \tau(1 - x_t^l) \quad (3.2.7)$$

This equality yields firm A's demand from loyal customers:

$$q_{AA,t}(p_{ot}^A, p_{nt}^B) = \min \left( \frac{\tau + s + p_{nt}^B - p_{ot}^A}{2\tau}, x_t \right) \quad (3.2.8)$$

Similarly,

$$q_{BB,t}(p_{ot}^B, p_{nt}^A) = \min \left( \frac{\tau + s + p_{nt}^A - p_{ot}^B}{2\tau}, 1 - x_t \right) \quad (3.2.9)$$

Note that the regular price does not affect demand from newcomers or switch-

ers, so firm  $i$  will choose  $p_{ot}^i$  independent of its own choice of  $p_{nt}^i$ . Thus, each firm sets  $p_{ot}^i$  to maximize profits from loyal customers taking as given the rival's introductory price. The choice of  $p_{ot}^i$  also determines the optimal mass of loyal customers that a firm would like to keep, given the introductory price of its rival. If this optimal mass exceeds the firm's actual market share, sales to loyal customers are limited to the size of the firm's existing customer base -  $x_t$  for firm A, and  $1 - x_t$  for firm B.

For  $c > 0$  firm A's regular price can be found as follows:

$$\max_{p_{ot}^A} (p_{ot}^A - c) \cdot \min \left( \frac{\tau + s + p_{nt}^B - p_{ot}^A}{2\tau}, x_t \right) \quad (3.2.10)$$

$$p_{ot}^A(p_{nt}^B) = \max \left( \frac{c + \tau + s + p_{nt}^B}{2}, \tau + s + p_{nt}^B - 2\tau x_t \right) \quad (3.2.11)$$

Similarly,

$$p_{ot}^B(p_{nt}^A) = \max \left( \frac{c + \tau + s + p_{nt}^A}{2}, s + p_{nt}^A + 2\tau x_t - \tau \right) \quad (3.2.12)$$

Note that the optimal regular price is increasing in the rival's introductory offer. For example, if  $p_{nt}^B$  is sufficiently large, firm A would keep all of its previous customers as loyal customers so  $q_{AA,t}$  will be constrained by firm A's market share. On the other hand, if  $p_{nt}^B$  is low enough, firm A's loyal customer segment will be less than  $x_t$ .

In the cases where sales to loyal customers are less than a firm's market share

I define  $\hat{q}_{ii,t}$  as firm  $i$ 's optimal sales to loyal customers in period  $t$ . One can further extend the interpretation of  $\hat{q}_{ii,t}$  as firm  $i$ 's optimal market share in period  $t$  if we consider situations in which the acquisition of market share is costly. Upon finding a deterministic optimal path for  $p_{nt}^A$  and  $p_{nt}^B$ , each firm can project what is the optimal market share to invest in today in order to maximize profits from loyal customers tomorrow. We can find  $\hat{q}_{AA,t}$  by plugging  $p_{ot}^A(p_{nt}^B)$  into (3.2.8), which yields  $\hat{q}_{AA,t}$  as a function of  $p_{nt}^B$  only:

$$\hat{q}_{AA,t}(p_{nt}^B) = \frac{\tau + s + p_{nt}^B - c}{4\tau} \quad (3.2.13)$$

Also,

$$\hat{q}_{BB,t}(p_{nt}^A) = \frac{\tau + s + p_{nt}^A - c}{4\tau} \quad (3.2.14)$$

Sales to loyal customers and the resulting profits can be summarized as follows:

$$q_{AA,t}(p_{nt}^B) = \min(\hat{q}_{AA,t}(p_{nt}^B), x_t) \quad (3.2.15)$$

$$\Pi_{ot}^A(p_{nt}^B) = \max\left(\frac{(\tau + s + p_{nt}^B - c)^2}{8\tau}, (\tau + s + p_{nt}^B - 2\tau x_t)x_t\right) \quad (3.2.16)$$

$$q_{BB,t}(p_{nt}^A) = \min(\hat{q}_{BB,t}(p_{nt}^A), 1 - x_t) \quad (3.2.17)$$

$$\Pi_{ot}^B(p_{nt}^A) = \max\left(\frac{(\tau + s + p_{nt}^A - c)^2}{8\tau}, (s + p_{nt}^A + 2\tau x_t - \tau)(1 - x_t)\right) \quad (3.2.18)$$

From (3.2.11) and (3.2.12) we can see that the optimal regular price is uniquely determined, given knowledge of the rival's introductory price. The assumption that firms set introductory and regular prices sequentially ensures that once the introductory prices are announced and firms set their regular prices accordingly, neither firm

has a profitable deviation in changing its regular price. Without this assumption, there may not be pure-strategy equilibria when the distribution of market shares is very unequal.

### Demand from switchers

Demand from switchers, if positive, can be represented as the difference between the rival's market share and its optimal sales of loyal customers. For firm A, demand from switchers is given by

$$q_{BA,t} = \max(0, (1 - x_t) - \hat{q}_{BB,t}) \quad (3.2.19)$$

Using (3.2.13), we find:

$$q_{BA,t}(x_t) = \max\left(0, \frac{3\tau - s - p_{nt}^A + c}{4\tau} - x_t\right) \quad (3.2.20)$$

Similarly, demand from switchers for firm B is given by:

$$q_{AB,t}(x_t) = \max\left(0, x_t - \frac{\tau + s + p_{nt}^B - c}{4\tau}\right) \quad (3.2.21)$$

From the demand equations in (3.2.20) and (3.2.21), it is clear that a firm's ability to poach depends on the pre-existing distribution of market shares, summarized in  $x_t$  – the firm that enters the period with low market share can attract the rival's previous customers at a higher price because of the closer proximity of prospective switchers. At the same time, both newcomers and switchers are offered

the same price,  $p_{nt}$ , so each firm chooses its optimal introductory price by balancing the incentives to gain market share and to maximize profits from poaching. Given the symmetry of the problem, if the firms' only goal was to capture market share, their introductory prices would be equal. However, the incentive to poach causes the introductory price to be dependent on market share, which leads to path dependence of current period profits. In fact,  $x_t$  is the only payoff-relevant state variable in period  $t$  that affects the choice variables  $p_{nt}^A$  and  $p_{nt}^B$ . The optimal regular price is unique for a given introductory price, so identifying the optimal pricing strategies for  $p_{nt}$  is sufficient to derive the full schedule of prices in period  $t$  as well as the distribution of the market at the beginning of period  $t + 1$ .

### The symmetric market equilibrium

I solve the dynamic problem for each firm by looking for a Markov Perfect Equilibrium (MPE), in which firms' pricing strategies depend solely on the realized distribution of the newcomers' market shares in the previous period. Specifically, based on the solution of a similar problem in Villas-Boas (1999), I look for a MPE, in which the price strategies regarding  $p_{nt}^i$  are piecewise affine in  $x_t$  and the value function of each firm is piecewise quadratic in  $x_t$ .<sup>18</sup> Again following Villas-Boas (1999) I assume that there is some minimal level of exit costs,  $E$ , that a firm would incur at the end of the period if it does not realize sales to newcomers in that period.<sup>19</sup> This assumption rules out the possibility that a pure-strategy equilibrium

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<sup>18</sup>Equilibria in non-affine strategies may also exist but they are outside the scope of our study. The equilibrium presented here is robust to deviations in affine strategies only.

<sup>19</sup>One can think of exit costs as arising from the loss of goodwill when the firm does not invest in market share. For example, if newcomers can obtain information about a firm's product only

may not exist when one firm starts out the period with a very small market share. It is necessary for some parameter ranges only and does not have a qualitative impact on the results that follow.

I characterize the equilibrium of the market for  $\delta_c = 1$  and  $s \leq \tau$ . There is switching in equilibrium, except when  $s = \tau$  in which case the equilibrium mass of switchers reaches zero.<sup>20</sup> Restricting attention to the limit of the consumer discount factor is justified for two reasons. First, letting  $\delta_c = 1$  allows us to derive intuitive closed-form solutions of the equilibrium price strategies. Second, as I will show below, competition intensifies as consumers become more patient. Thus, assuming  $\delta_c = 1$  allows us to focus on the most competitive version of this market, which is in line with our interest in analyzing whether competition hinders information sharing. I discuss how lower values of the consumer discount factor affect the equilibrium results in Section 3.2.3.

**Proposition 1.** *Let  $\delta_f \in (0, 1)$ ,  $\delta_c = 1$ ,  $s \leq \tau$ , and  $E \geq \frac{(3\tau-s)^2 - 2\delta_f(\tau+s)^2}{16\tau}$ . A unique*

*Markov-perfect equilibrium in affine strategies exists and can be characterized as*

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through existing loyal customers, a firm that made no sales to newcomers in the past period may have to incur expenditures on promoting its product.

<sup>20</sup>For a discussion of the equilibrium when  $s > \tau$  see Grozeva (2009).

follows:

$$p_{nt}^A = p_{nt}^B = c \quad (3.2.22)$$

$$p_{ot}^A = \max \left( c + \frac{\tau + s}{2}, \tau + s + c - 2\tau x_t \right) \quad (3.2.23)$$

$$p_{ot}^B = \max \left( c + \frac{\tau + s}{2}, \tau + s + c - 2\tau(1 - x_t) \right) \quad (3.2.24)$$

$$\hat{q}_{AA} = \hat{q}_{BB} = \frac{\tau + s}{4\tau} \quad (3.2.25)$$

$$q_{AB} = \max(0, x_t - \hat{q}_{AA}) \quad (3.2.26)$$

$$q_{BA} = \max(0, 1 - x_t - \hat{q}_{BB}) \quad (3.2.27)$$

$$x_{t+1} = 1/2 \quad \forall x_t \in [0, 1] \quad (3.2.28)$$

*Proof.* All proofs are contained in the Appendix. □

In equilibrium, the price to new customers equals marginal cost and is independent of market share, loyal customers are charged a premium, and the market is equally split. To provide intuition for these results I present certain features of the market equilibrium in the following lemmas. I first draw attention to the property that demand from newcomers becomes more elastic as  $\delta_c$  increases.<sup>21</sup>

**Lemma 1.** *Competition for newcomers intensifies as consumers become more patient. As a result,  $p_n^i$  and  $p_o^i$  fall as  $\delta_c$  goes up.*

The next property is closely related to Lemma 1. I find that as consumers become very patient, i.e.  $\delta_c = 1$ , newcomers' demand becomes perfectly elastic.

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<sup>21</sup>This property is also present in Villas-Boas' model of dynamic competition where switching costs are zero. (Villas-Boas, 1999)

**Lemma 2.** *When  $\delta_c = 1$ , demand from newcomers is perfectly elastic.*

Lemmas 1 and 2 help explain why the introductory prices do not fall below marginal cost despite the positive return on market share and the perfect elasticity of demand. Lemma 2 shows that when  $\delta_c = 1$  competition for market share can be characterized by Bertrand price competition with homogeneous goods. Unlike most models with switching costs and product homogeneity where all future profits from customer lock-in are dissipated in the competition for market share, in this setting firms do not have an incentive to undercut when the price falls down to marginal cost. First, when  $p_n = c$  additional sales to newcomers do not increase profits. Second, since demand from newcomers is perfectly elastic, consider a market sharing rule such that the market is split anywhere within the  $(\hat{q}_{AA}, 1 - \hat{q}_{BB})$  range whenever consumers are indifferent between the two firms. Profits from new customers are zero, so a sharing rule that allows firms to capture at least their future loyal customers will be robust to unilateral deviations. For example, if firm A can capture customers in  $(0, \hat{q}_{AA})$ , i.e. its future loyal customers, selling to newcomers located outside this range does not raise firm A's profits neither in the present period, nor in the next period. At this point, I assume that the market is equally split in case of a tie and consumers in each half of the market buy from the firm that is closest to them. In the next sections, we will see that the sharing rule has to be modified to guarantee existence of a pure-strategy equilibrium.

Proposition 1 reveals that the equilibrium introductory price is independent of the current distribution of the market, given by  $x_t$ . This is due to the fact that



sales to switchers are profit-neutral and  $x_t$  becomes irrelevant in the determination of  $p_{nt}$ .<sup>22</sup> It also follows that convergence to steady state,  $\bar{x} = 1/2$  under the equal sharing rule, occurs in just one period. This result is summarized in the next corollary:

**Corollary 1.** *Under the conditions outlined in Proposition 1 and given  $x_t \in [0, 1]$  the market converges to steady state,  $\bar{x} = 1/2$ , in just one period.*

From the equilibrium price expressions we can see that the introductory price is independent of  $s$  while the regular price is increasing in  $s$ . Naturally, sales to loyal customers increase in  $s$  while sales to switchers decrease in  $s$ . Therefore, firm profits unambiguously increase in the magnitude of the switching cost and competition becomes more relaxed as switching costs increase. Similarly, firm profits are increasing in the degree of product differentiation, as higher transportation costs further relax competition. Positive steady-state per-period firm profits arise solely from profits in the loyal customer segment of the market and are given by:

$$\Pi^* = \frac{(\tau + s)^2}{8\tau} \rightarrow \frac{\tau}{2} \quad \text{as } s \rightarrow \tau \quad (3.2.29)$$

### 3.2.3 The decision to share information

I now examine how the market equilibrium changes when one firm experiences a higher incidence of contract breach relative to its rival as this will illustrate how

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<sup>22</sup>It should be noted that for some parameter values, it is the presence of exit costs that guarantees that a firm with no market share would choose to compete for newcomers instead of raising its price and targeting switchers exclusively. However, the presence of exit costs will not have a qualitative effect on the rest of the results.

the latter can benefit from withholding information. I first characterize the equilibrium path following a period of cost asymmetry. Corollary 1 facilitates the analysis because the impact of a transitory, one-period cost shock will be limited to this period's strategies only – as soon as cost symmetry is restored next period, firms' strategies will depend on the current distribution of the market only and the market reaches steady state in the subsequent period.

### The impact of an asymmetric cost shock

In the absence of a shock, in period  $t$  the equilibrium prices are given by:

$$p_n^* = c, \quad p_o^* = c + \frac{\tau + s}{2} \quad (3.2.30)$$

and the corresponding sales to newcomers, loyal customers and switchers as

$$q_{1i}^* = 1/2, \quad q_{ii}^* = \frac{\tau + s}{4\tau}, \quad q_{ij}^* = \frac{\tau - s}{4\tau} \quad (3.2.31)$$

while steady-state profits are given by (3.2.29). As long as the firms are facing symmetric marginal costs and the market is on the equilibrium path, these values are identical across the two firms, so I suppress the firm-specific notation for the steady-state values from now on.

Consider the general case where in period  $t - 1$  firm  $j$ 's default rate is higher than of the rival so in period  $t$  it operates with marginal cost  $\tilde{c} > c$ , reflecting the additional cost of securing funds. The shock's magnitude is given by  $\Delta c = \tilde{c} - c$ ,

where  $\Delta c > 0$ . The shock lasts one period only and its duration and magnitude are common knowledge. Firm  $i$ 's cost is unchanged and equal to  $c$ . At this point, I seek to characterize the equilibrium outcome in period  $t$  and assume that the shock is unanticipated by both firms. This assumption will be relaxed in Section 3.2.3

In order to derive the equilibrium in the period in which the shock occurs, I present two lemmas that help us analyze firm behavior when the market goes through a period of cost asymmetry. I will discuss firms' best responses in terms of their introductory prices only, because the regular prices are set sequentially and are conditional on the rival's introductory price. Recall from Corollary 1 that as soon as symmetry is restored, the market converges to steady state in just one period. Thus, both firms correctly anticipate that after a shock in period  $t$ , in the equilibrium introductory price in period  $t + 1$  will be equal to its steady-state level,  $p_n^* = c$ , and profits from loyal customers will depend on market share gained in period  $t$ . The following two lemmas hold regardless of the current distribution of the market.

**Lemma 3.** *Let  $p_{nt}^{i*}$  indicate firm  $i$ 's best response to the rival's price,  $p_{nt}^j$ . Then,*

(a)  $p_{nt}^{i*} < p_{nt}^j$ , when  $p_{nt}^j > c^i$  (firm  $i$  undercuts);

(b)  $p_{nt}^{i*} \geq p_{nt}^j$  when  $p_{nt}^j \leq c^i$  (firm  $i$  matches or exceeds the rival's price).

Part (a) of Lemma 3 states that whenever the rival's introductory price is above firm  $i$ 's marginal cost, firm  $i$  has an incentive to undercut because it can capture the entire market of newcomers by lowering its price just below the rival's price,  $p_{nt}^j$ . Since  $p_{nt}^j > c^i$  firm  $i$ 's sales to newcomers are profitable and a discrete

increase in the demand from newcomers justifies a price decrease. Furthermore, for some parameter values it is possible that firm  $i$ 's optimal response is to lower its price well below  $p_{nt}^j$  in order to optimize profits from switchers and newcomers. In either case, firm  $i$ 's best response is to sell below the rival's price.

The second part of Lemma 3 states that if the rival's price is below firm  $i$ 's marginal cost, firm  $i$  can take on two actions. On one hand, it can match the rival's price, effectively selling at a price below cost. Unless the rival's price is too low, this is a best response for any market sharing rule that allows the firm to capture at least its loyal customer segment when prices are equal. On the other hand, firm  $i$  can set a price above the rival's and target switchers only. In that case, Lemma 2 points out that demand from newcomers will be zero so firm  $i$  will forgo the payoff from establishing market share. To establish which one of these two actions would be a best response for firm  $i$ , we need to consider the corresponding stream of profits from either strategy. Since the market reverts to its steady-state equilibrium next period, the decision to invest in market share today or target switchers exclusively will only affect profits from loyal customers in period  $t+1$  but it will have no impact on the firm's stream of profits in periods  $t+2$  and onwards. Note that the future value of market share and the presence of exit costs when the firm makes no sales to newcomers motivate firms to sell at an introductory price below cost when necessary. However, if this price is too low, firm  $i$  may be better off raising its introductory price above cost and selling to switchers only.<sup>23</sup>

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<sup>23</sup>The minimum level of exit costs is not sufficient to deter firm  $i$  from taking this action because the discounted payoff from market share is lower when the introductory price is below cost.

Let  $\underline{p}^i$  indicate firm  $i$ 's 'break-even' introductory price, i.e. the introductory price that renders firm  $i$  indifferent between investing in market share (by lowering its price to the rival's level) and targeting switchers only (by raising its price above cost). If the rival's price is below firm  $i$ 's break-even price, firm  $i$ 's payoff from targeting switchers exceeds the payoff from investing in market share so firm  $i$ 's best response is to raise its price above cost. Otherwise, firm  $i$  is better off matching the rival's price and capturing market share. This result is summarized in the next lemma, which characterizes firm  $i$ 's best response in terms of  $\underline{p}^i$ , conditional on the rival's price being equal to or below firm  $i$ 's cost.

**Lemma 4.** *If  $p_{nt}^j \leq c^i$  there exists a break-even price  $\underline{p}^i(c^i) < c^i$  such that*

(a)  $p_{nt}^{i*}(p_{nt}^j) = p_{nt}^j$  when  $p_{nt}^j \geq \underline{p}^i$ ;

(b)  $p_{nt}^{i*}(p_{nt}^j) > p_{nt}^j$  when  $p_{nt}^j < \underline{p}^i$ .

Based on these two lemmas we can characterize the equilibrium during a period of cost asymmetry. Suppose that firm A receives a cost shock in period  $t$ . It operates at marginal cost  $\tilde{c}$  for the duration of the period. Proposition 2 characterizes the equilibrium in period  $t$ , conditional on  $x_t = 1/2$ , i.e. the market is currently in steady state:

**Proposition 2.** *Let  $\underline{p}^A$  designate firm A's break-even price. Under the conditions outlined in Proposition 1, there exist threshold values  $\overline{\Delta c}$  and  $\underline{\Delta c}$ , such that a subgame-perfect pure-strategy equilibrium in period  $t$  exists and can be characterized as follows:*

(a) If  $\Delta c \leq \overline{\Delta c}$ , then

$$p_{nt}^A = p_{nt}^B = c, \quad (3.2.32)$$

$$p_{ot}^A > p_o^*, \quad p_{ot}^B = p_o^*, \quad (3.2.33)$$

$$q_{AA,t} < q_{AA}^*, \quad q_{BB,t} = q_{BB}^*, \quad (3.2.34)$$

$$x_{t+1} = 1/2 \quad (3.2.35)$$

$$\Pi_{A,t} < \Pi^*, \quad \Pi_{B,t} = \Pi^* \quad (3.2.36)$$

$$\Pi_{A,t+1} = \Pi^*, \quad \Pi_{B,t+1} = \Pi^* \quad (3.2.37)$$

(b) If  $\Delta c \geq \underline{\Delta c}$ , where  $\underline{\Delta c} > \overline{\Delta c}$ :

$$p_{nt}^A = \underline{p}^A > c, \quad p_n^* < p_{nt}^B < \underline{p}^A, \quad (3.2.38)$$

$$p_{ot}^A > p_o^*, \quad p_{ot}^B > p_o^*, \quad (3.2.39)$$

$$q_{AA,t} < q_{AA}^*, \quad q_{BB,t} > q_{BB}^*, \quad (3.2.40)$$

$$x_{t+1} = 0 \quad (3.2.41)$$

$$\Pi_{A,t} < \Pi^*, \quad \Pi_{B,t} > \Pi^* \quad (3.2.42)$$

$$\Pi_{A,t+1} < \Pi^*, \quad \Pi_{B,t+1} = \Pi^* \quad (3.2.43)$$

*These strategies describe the unique pure-strategy equilibrium when  $\Delta c \geq \underline{\Delta c}$ .*

*When  $\Delta c \in (\overline{\Delta c}, \underline{\Delta c})$ , there is no equilibrium in pure strategies. For all values of  $\Delta c$  the market reverts to the equilibrium characterized in Proposition 1 in period  $t + 1$ .*

From part (a) of Proposition 2 we see that a sufficiently small cost shock ( $\Delta c \leq$

$\overline{\Delta c}$ ) does not disturb the market away from its symmetric-cost equilibrium aside from firm A's adjustment of the price to loyal customers to reflect its higher marginal cost. Consequently, firm B's profits remain unchanged despite its temporary cost advantage. This important result illustrates that the low-cost firm does not realize any benefits from the distress of its rival when the cost shock to the latter is not too big. The intuition for this result is based on the observation that for  $\delta_c = 1$  demand from newcomers is perfectly elastic. Suppose that firm B sets  $p_{nt}^B = c$ . Lemma 3 states that undercutting is not a best response for firm A when the rival's price is below firm A's marginal cost. Therefore, A can match B's price and capture half of the newcomers market or it can set a higher price and sell to switchers only. Matching the rival's price is costly for firm A because the rival's price is below firm A's cost. Hence, firm A would incur a loss of  $\tilde{c} - c$ , equivalent to  $\Delta c$ , for each unit sold to a new customer. The payoff from doing so is equal to the profit realized on the loyal customers next period and the exit costs that are avoided by the acquisition of market share. By finding the highest value of  $\Delta c$  such that firm A is willing to invest in market share, we identify an upper limit on firm A's cost shock,  $\overline{\Delta c}$ . As long as  $\Delta c \leq \overline{\Delta c}$  firm A's best response is to match the rival's price because this allows it to capture market share. Note also that firm A's break-even price,  $\underline{p}^A$ , can be identified by  $\underline{p}^A = \tilde{c} - \overline{\Delta c}$ .

Part (b) of Proposition 2 describes the impact of a 'large' shock, i.e.  $\Delta c > \overline{\Delta c}$ . When A's cost shock is large, it cannot compete successfully for new customers in period  $t$ . Upon setting  $p_{nt}^A = \underline{p}^A$ , firm A is outbid by firm B because  $\underline{p}^A$  is greater

than B's marginal cost (Lemma 3).<sup>24</sup> Firm B captures the full market of newcomers today at a price above its own cost. The main implication of this result is that given the realization of a large shock to firm A, firm B realizes higher profits from all three customer segments in period  $t$ . In particular, it is able to maintain an introductory price above cost and sell to all newcomers while its regular price and the size of the loyal customer segment increase as well because the rival's introductory price is above  $p_n^*$ .<sup>25</sup> Thus, it realizes higher profits from both segments of the market in period  $t$ . In period  $t + 1$ , cost symmetry is restored, firm B realizes its normal level of profits, while firm A makes zero profit because it had failed to build a loyal customer base. The market goes back to steady state at the end of period  $t + 1$ .

Note also that for intermediate values of  $\Delta c$  there is no equilibrium in pure strategies. The condition  $\Delta c > \underline{\Delta c}$  is stronger than  $\Delta c > \overline{\Delta c}$  – the latter condition implies that A cannot compete for newcomers while the former also ensures that firm A faces no demand from switchers at all. Hence, when  $\Delta c > \underline{\Delta c}$  A does not have a profitable deviation in raising its price away from  $\underline{p}^A$  once it has been undercut. A profitable deviation would exist if firm A faced demand from switchers at  $\underline{p}^A$ ; therefore,  $\Delta c > \underline{\Delta c}$  is needed to ensure that firm A's cost is sufficiently high to induce no demand from switchers. I do not characterize the equilibrium with mixed strategies but note that as  $s \rightarrow \tau$ , the range of  $\Delta c$ , for which pure-strategy equilibria do not exist, approaches the empty set,  $(\overline{\Delta c} \rightarrow \underline{\Delta c})$ .<sup>26</sup> Furthermore, it will be shown

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<sup>24</sup>Alternatively, firm B may set  $p_{nt}^B = \underline{p}^A$  and this strategy may still be a candidate for an equilibrium if the market sharing rule is modified to split the market  $x_{t+1} = 0$ . For clarity, I suppose that firm B outbids A by setting a slightly lower price.

<sup>25</sup>Recall from (3.2.13) that  $\partial \hat{q}_{ii,t} / \partial p_{nt}^j > 0$ .

<sup>26</sup>See the proof to Proposition 2 for more details.



that  $\overline{\Delta c} \equiv \underline{\Delta c}$  when the shock is anticipated since the market distribution from the preceding period will be such that  $q_{BA,t}$  will be zero.

As demonstrated in the proof to Proposition 2, in the presence of a small shock the equilibrium is not unique. Any pair of prices such that  $p_{nt}^A = p_{nt}^B = p$  and  $p \in [\underline{p}^A, c]$  would constitute a Nash equilibrium in period  $t$  and a subgame perfect equilibrium of the subgame from period  $t$  onwards. Part (a) of Proposition 2 presents the Pareto-optimal equilibrium, assuming that this is the equilibrium that firms will coordinate on. Intuitively,  $p_{nt}^A = p_{nt}^B = c$  is not the unique equilibrium ( despite the framework's similarity to the model of Bertrand competition with homogeneous market demand), because sales today also represent an investment in market share. Firms are willing to sustain small losses today and sell below cost in order to gain market share that will bring in profits tomorrow. The perfect elasticity of demand makes deviations above the rival's price unprofitable and if for any reason one firm sets a price slightly below cost, the other firm is forced to match this price in order to capture any market share at all. The lower bound on the price range within which all identical prices constitute an equilibrium is determined by  $\max(\underline{p}^A, \underline{p}^B)$ . When firms are symmetric, firms' break-even prices are identical so  $\underline{p}^A = \underline{p}^B$  is an equilibrium that exhausts profits from future market for both firms. In the asymmetric cost case here, this lower bound is given by the price that exhausts all future profits for the high-cost firm – this is  $\underline{p}^A$  in Proposition 2. If firm A sets  $p_{nt}^A = \underline{p}^A$  and, firm B has no profitable deviation in undercutting this price (the shock is small,  $\underline{p}^A < c$ ) or raising its price above  $\underline{p}^A$  (which would imply gaining no market share).

We can now move on to identify the strategic cost of information sharing by allowing for the cost shock to be anticipated as firms can foresee if the rival has an incentive to deviate.

### The strategic cost of information sharing

The results from Propositions 1 and 2 can now be applied to illustrate how the magnitude of the strategic cost of information sharing depends on the firms' liquidity positions. I define this strategic cost as the additional profits that a firm will realize if it deviates from the information-sharing agreement by withholding information from its rival. In terms of the notation in Figure 3.2 the strategic cost is given by  $m - n$ .

In the discussion of the market equilibrium in Sections 3.2.2 and 3.2.3 above we assumed that there is no uncertainty regarding the realization of the firms' marginal costs. However, if next period costs are uncertain, firms' price strategies will be as described in Proposition 1 as long as both firms have the same expected marginal costs. Consumers have perfect foresight and anticipate that in expectation next period the two firms' introductory prices will be equal – therefore, newcomers are still indifferent between the two firms if they offer equal prices today.<sup>27</sup> Also, in expectation next period's optimal market share,  $\hat{q}_{ii}$ , is unchanged for both firms because the expected profit margin on loyal customers stays the same (and is equal to  $(\tau + s)/2$ ). Therefore, firms have no incentive to alter their price strategies when their expected marginal costs are symmetric; hence, Proposition 1 still applies. Note

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<sup>27</sup>The marginal newcomer will be indifferent between the two firms since  $p_{nt}^A + \tau x_t + (p_{nt+1}^B + \tau(1 - x_t) + s) = p_{nt}^B + \tau(1 - x_t) + (p_{nt+1}^A + \tau x_t + s)$  when  $p_{nt}^A = p_{nt}^B$  and  $p_{nt+1}^A = p_{nt+1}^B$ .

also that as long as both firms take the same action in the information sharing game – ‘Share’ or ‘Do not share’, – they face symmetric risk of default. If we also impose the assumption that they have the same cost of funds, then their expected marginal costs are also symmetric and Proposition 1 characterizes the equilibrium in all periods, in which an asymmetric cost shock does not occur and is not anticipated in the next period.

Now consider the situation where one firm shares information while the other one does not. The firm that unilaterally shared information is exposed to higher default risk relative to its rival – therefore, next period its marginal cost will be above the rival’s marginal cost. This scenario is captured in the discussion of the equilibrium with asymmetric costs (Proposition 2). Note that within the context of the supergame of information sharing, firms are i) assumed to detect deviations with no lag; and ii) assuming that the rival’s liquidity position is common knowledge, each firm correctly anticipates whether the rival will deviate from the information sharing agreement. Hence, the shock that will result from the deviation of one firm will be anticipated by both firms. The anticipation of the shock may, in turn, affect the firms’ price strategies in the preceding period. Therefore, we need to examine firms’ price strategies in the period preceding the shock.

*The equilibrium in the period preceding the shock*

Since a deviation is most profitable at the beginning of the supergame, we will consider a deviation occurring in period 1 that causes a cost shock to the rival in period 2. This implies that firms declare their willingness to share information in

period 0 and they have their first opportunity to do so at the beginning of period 1.<sup>28</sup> In line with the discussion of Proposition 2 suppose that firm B deviates by withholding information at the beginning of period 1 so that firm A is exposed to a higher risk of default in that period. The default rate is discovered at the end of period 1 and firm A incurs costs to secure liquid assets needed in period 2. As a result, it will operate at a higher marginal cost in period 2 and the equilibrium price strategies in that period are described by Proposition 2. The next proposition characterizes a pure-strategy equilibrium of the subgame in period 1 when both firms anticipate that firm A will be hit by an adverse cost shock of magnitude  $\Delta c$  in period 2 as a result of firm B's deviation.

**Proposition 3.** *Let Proposition 2 characterize the anticipated outcome in period 2. Under the general conditions outlined in Proposition 1, there exists a pure-strategy Nash equilibrium in period 1, characterized as follows:*

(a) *If  $\Delta c \leq \overline{\Delta c}$ , then*

$$p_{n,1}^A = p_{n,1}^B = c \quad (3.2.44)$$

$$x_2 = 1 - q_{BB}^* \quad (3.2.45)$$

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<sup>28</sup>Considering a deviation in period 0 also significantly simplifies the problem as we do not have to consider how the anticipation of a cost shock will affect firms' price strategies in all preceding periods.

(b)

$$p_{n,1}^A = p_{n,1}^B = c \quad (3.2.46)$$

$$x_2 = 1 - q_{BB,2}^* \quad (3.2.47)$$

*Under the period-1 strategy profiles described above, in period 2  $\overline{\Delta c} \equiv \underline{\Delta c}$  and there exists a pure-strategy equilibrium for all values of the cost shock.*

The anticipation of next period's shock affects the expected returns to market share. When the anticipated shock is small, firm B correctly anticipates that its return on market share remains unchanged while firm A's profits decrease. If firm B maintains a price equal to marginal cost at period 1, firm A can costlessly invest in market share by matching this price. Any market sharing rule that allows each firm to capture its loyal customers segment will be sufficient to guarantee that neither firm will deviate from the proposed equilibrium.

When the anticipated shock is large, here  $\Delta c > \overline{\Delta c}$ , firm B realizes larger gains on its loyal customers segment and its optimal market share in period 2 is larger than its steady-state level ( $\hat{q}_{BB,2} > q_{BB,2}^*$ ). At the same time, A's optimal market share shrinks because it realizes smaller (or zero) profits from its loyal customers in period 2. If  $\hat{q}_{AA,2} + \hat{q}_{BB,2} \leq 1$ , the firms can continue selling at marginal cost in period 1 and, again, under a sharing rule that allows each firm to keep its respective loyal customer segment, neither firm will deviate from the proposed equilibrium,  $p_{n,1}^A = p_{n,1}^B = c$ . In the proof of this proposition it is shown that  $\hat{q}_{AA,2} + \hat{q}_{BB,2}$  is

always less than one.

Similar to the period-2 equilibrium when firm A is hit by a ‘small’ shock, the period-1 equilibrium described in Proposition 3 is not unique. Under the sharing rule  $x_2 = 1 - \hat{q}_{BB,2}$  in case of a tie, any price pair  $(p_n^A, p_n^B)$  where  $p_n^A = p_n^B = p$  and  $p \in [\max(\underline{p}_1^A, \underline{p}_1^B), c]$  would be an equilibrium in period 1.<sup>29</sup>

We see that regardless of the magnitude of the anticipated shock, neither firm changes its optimal price strategy in period 1 - both firms continue to set  $p_n^A = p_n^B = c$ . This implies that firms will not change their equilibrium price strategies in period 0 either. Recall that firms agree to share information in period 0 so the anticipation that one firm may deviate could have affected their period-0 price strategies. The results in Proposition 3 show that despite the anticipation of one firm deviating (in this case, firm B), firms optimal price strategies in periods 1 and 2 remain the same, where the price rigidity in the market is largely due to the interaction of the perfectly elastic newcomers’ demand and the profitability of the mature market.

Finally, note that there is only one relevant threshold level in period 2 as  $\overline{\Delta c} \equiv \underline{\Delta c}$ . By splitting the market at  $x = 1 - \hat{q}_{BB,2}$ , firm A will face no demand from switchers in period 2 as firm B will retain all of its customers – in period 1 firm B captures only its future loyal customers. Under this distribution of the market, by applying Proposition 2 we see that there is a pure strategy equilibrium in period 2 for all values of  $\Delta c$ . Recall that in the case where firm B successfully outbids

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<sup>29</sup> $\underline{p}_1^A$  and  $\underline{p}_1^B$  are the period-1 break-even prices for firm A and firm B, respectively. Their derivation is similar to the derivation of  $\underline{p}^A$  in the proof of Proposition 2.

A pure-strategy equilibrium exists as long as firm A has no profitable deviation in raising its price, e.g. when it faces no demand from switchers when its price is below cost. In the derivation of the equilibrium during a period of cost asymmetry in Proposition 2, it was assumed that firms begin the period with equal market shares and firm A faces demand from switchers unless its break-even price is sufficiently high. In contrast, when the market in period 2 is distributed such that  $q_{BA,2} = 0$ , the condition that firm A's break-even price is sufficiently high becomes obsolete: even when firm A is outbid (i.e. when  $\Delta c > \overline{\Delta c}$ ), it has no profitable deviation in raising its price above  $\underline{p}^A$ . As a result,  $\overline{\Delta c} \equiv \underline{\Delta c}$ .

Proposition 3 shows that firm B's potential gains from its cost advantage in period 2 are not dissipated through the competition for market share in period 1. Recall that firm B profits from its cost advantage only if A's shock is sufficiently large. We see that anticipating a large shock in period 2 also does not change the equilibrium prices in period 1.

### The role of liquidity

All else equal, when one firm experiences a higher risk of default relative to its rival, the size of the cost disparity is determined by this firm's cost of funds. Therefore, I will refer to  $\overline{\Delta c}$  as the liquidity threshold that determines whether a firm is 'liquid', i.e.  $\Delta c \leq \overline{\Delta c}$  or 'liquidity-constrained', i.e.  $\Delta c > \overline{\Delta c}$ .

**Proposition 4.** *In a market with customer recognition, heterogeneous goods, homogeneous switching costs, and infinitely patient consumers, a firm's strategic cost of information sharing is zero when its rival is liquid ( $\Delta c_{rival} \leq \overline{\Delta c}_{rival}$ ) and strictly*

*positive when its rival is liquidity constrained* ( $\Delta c_{rival} > \bar{\Delta} c_{rival}$ ).

Proposition 4 states our main result: firms who have cheap access to liquid assets endure a small cost shock when their rival deviates by withholding information. As a result, the rival does not derive any benefits from its deviation. In contrast, when a firm is liquidity-constrained it is vulnerable to information asymmetries and the rival profits from withholding information. Hence, a firm's temptation to deviate from the information sharing agreement is strictly positive only when the firm's rival is liquidity-constrained.

This proposition makes two important contributions. First, it pins down the key role of liquidity on the cost of sharing information with a rival – firms realize that they can only benefit from the distress of their rivals if the latter are liquidity constrained. Second, in light of the market setup so far Proposition 4 identifies conditions, under which imperfect competition does not discourage information sharing, i.e. the strategic cost of disclosing information can be as low as zero. A simpler differentiated-goods duopoly model would not produce this result, which emphasizes the need to extend the analysis of competition and information sharing to a richer market framework. In this example, it is the interaction of features such as customer recognition, overlapping generations of infinitely patient consumers and product differentiation that produce this finding.

We can use Proposition 4 to make predictions about the market characteristics that foster information flows between rivals. If the firms within a market are very dissimilar in their cost of funds, such that one firm is liquid while the other is liquidity



constrained, then the liquid firm has an incentive to deviate and information sharing can be sustained only if the that firm is sufficiently patient. Now suppose that firms who share a market have similar liquidity positions so that they are either both liquid or both are liquidity constrained – we will refer to such markets as homogeneous. In a market populated by liquid firms, the strategic cost of sharing information is zero for both firms, so neither of them has any incentive to deviate from the information sharing agreement. In the context of the exposition in Section 3.2.1 and Figure 3.2, when firms are liquid we have that  $m = n$ . This equality implies that sharing information is a Nash equilibrium of the one-shot game in Figure 3.2. Since it is also the Pareto-optimal equilibrium, information sharing is a matter of coordinating on the desirable equilibrium outcome. In contrast, in a market with liquidity constrained firms the strategic cost of information sharing is positive:  $m > n$ . The only Nash equilibrium in the one-shot game is  $(Share, DoNotShare)$  but the payoffs  $(k, k)$  are not Pareto optimal. By a straight-forward application of the Folk theorem (Friedman, 1971), liquidity-constrained firms will play the cooperative strategy of sharing information if the discounted long-term benefits of doing so outweigh the short-term gains from deviating. Based on this discussion we can formulate the following testable hypothesis:

**Hypothesis 1.** *If the net benefits of information sharing are strictly positive and firms within a market are homogeneous in the cost of securing liquid funds, all else equal, information sharing is more likely to be sustained in markets populated by liquid firms relative to markets populated by liquidity constrained firms.*

This hypothesis will be tested in Section 3.3.1.

### **The role of competition**

One of our main questions of interest is whether the strategic cost of information sharing is higher under more intense competition. Therefore, we can examine how the liquidity threshold  $\overline{\Delta c}$  varies with competition. If  $\overline{\Delta c}$  falls, then the requirement that the shock is small become more stringent – there is a higher probability that some firms will face a positive strategic cost. Thus, more intense competition would decrease the likelihood that information sharing occurs. It is our goal to establish how  $\overline{\Delta c}$  varies with changes in the competition parameters. As mentioned earlier, the degree of competition in the market varies along three dimensions – consumer patience ( $\delta_c$ ), the degree of product differentiation in the market (proxied by  $\tau$ ), and the level of switching costs ( $s$ ). Since we limit attention to  $\delta_c = 1$ , the endogenously determined liquidity threshold  $\overline{\Delta c}$  depends explicitly on  $s$  and  $\tau$  and we can perform comparative statics. The analysis of how  $\overline{\Delta c}$  varies with  $\delta_c$  is not so straight-forward because the model is not tractable for  $\delta_c$  away from one. For this reason, I present some intuition for the market dynamics when  $\delta_c$  is away from one and then discuss how a temporary cost asymmetry may affect the firms' price strategies. This discussion will illustrate how more intense competition can reduce the strategic cost of information sharing to zero and facilitate information sharing.

As shown in Villas-Boas (1999), greater consumer patience intensifies competition for newcomers and lowers both the introductory and regular prices. This result is confirmed in Grozeva (2009) for the augmented model of dynamic com-

petition with switching costs, which is used here. As competition becomes more intense, newcomers' demand becomes more elastic and the high-cost firm has less flexibility in adjusting its introductory price in response to the cost shock. In the limit, when  $\delta_c \rightarrow 1$ , we saw that the high-cost firm cannot raise its introductory price without losing demand from all newcomers. This produced the equilibrium result that for a small shock, price remains unchanged and the low-cost firm realizes no additional benefits from its cost advantage. This ensured that the strategic cost of information sharing can be as low as zero. If newcomers' demand was not perfectly elastic, the high-cost firm would be able to raise its price and still capture market share. The rival's best response then would be to also raise its price. The difference between the two prices will depend on the discount factors of firms and consumers. This is driven by the fact that convergence to steady state is monotonic and becomes slower as firms become more patient – firms realize that larger market share hampers their ability to compete for switchers next period so they compete less aggressively for new customers today. Hence, the low-cost firm will raise its price in response to the price increase by the firm experiencing the shock and the more patient firms are, the closer the two prices will be to each other. All of this implies that when  $\delta_c < 1$  a temporary cost asymmetry will always generate additional benefits to the low-cost firm because it allows it to charge higher prices to all customer segments and increases its sales to new and loyal customers. At the same time, the losses of the high-cost firm are mitigated by the firm's ability to raise its price without entirely forgoing sales to newcomers. In summary, when  $\delta_c < 1$  the strategic cost of information sharing will be strictly positive ( $m > n$ ) for all values

of the cost shock. A lower consumer discount factor makes competition less intense, thereby increasing the strategic cost of information sharing. This suggests that in a less competitive market, where the degree of competition is only varied along the consumer discount factor, a self-enforcing information-sharing agreement will be harder to sustain because it is more costly. This argument provides a counterpoint to the perception that more intense competition is necessarily more detrimental to information-sharing practices.

What happens when competition varies with the degree of product differentiation or switching costs? Limiting attention to  $\delta_c = 1$  allows us to perform comparative statics with respect to the liquidity threshold,  $\overline{\Delta c}$ . The next corollary describes how the liquidity threshold varies with the degree of product differentiation and switching costs:

**Corollary 2.** *Under the conditions presented in Propositions 2 and 3, the liquidity threshold,  $\overline{\Delta c}$ , increases in the magnitude of switching costs and the degree of product differentiation.*

Not surprisingly, the liquidity threshold increases in  $s$  and  $\tau$  because they increase the value of market share. As market share becomes more valuable the break-even price of the affected firm falls even lower so the liquidity threshold goes up. It should be noted, however, that the result with respect to  $\tau$  can be ambiguous if the distribution of the market was such that firm A faced demand from switchers during the period of the shock.

When  $\delta_c = 1$ , increases in switching and transportation costs unambiguously

relax competition. The equilibrium introductory price is independent of  $s$  and  $\tau$  while the regular price increases in both parameters.<sup>30</sup> Sales to loyal customers, the profitable customer segment in the market, also increase as switching and transportation costs go up. Holding the cost of liquid funds constant, more intense competition through lower  $s$  and  $\tau$  lowers the liquidity threshold, making the liquidity requirement more stringent. This increases the strategic cost of information sharing for those firms, whose cost of funds was below the original liquidity threshold and is now above the new threshold. The proof of Corollary 2 also shows that the cross-partial derivatives,  $\frac{\partial^2 \overline{\Delta c}}{\partial s \partial \tau}$  and  $\frac{\partial^2 \overline{\Delta c}}{\partial \tau \partial s}$ , are negative. This indicates that the rate at which higher switching costs raise the liquidity threshold is lower when there is already a large degree of product differentiation (and vice versa). This finding is intuitive because higher switching and transportation costs raise the return on market share (given by  $(\tau + s)/2$  per unit sold) and, therefore, raise the liquidity threshold. If the return on market share is already high due to large product differentiation, the relative effect of the switching costs on the return to market share is smaller.

The result in this section is important because it provides an analysis of how parameters defining the ex-ante level of competition affect information sharing. Past studies of information sharing and competition have looked at the interaction of the two as in their models information sharing relaxes or intensifies competition and the desirability of an information-sharing regime depends on the change in the compet-

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<sup>30</sup>For  $\delta_c < 1$  and complete customer lock-in (the case where  $s > \tau$ ), switching costs intensify the competition for market share as they increase the return from loyal customers.

itive environment.<sup>31</sup> In contrast, in our model, we are able to determine how the ex ante competition intensity affects information sharing. If competition intensity is driven by variation in switching or transportation costs, then the strategic cost of information sharing is on average higher in more competitive markets. In addition, our dynamic model also identifies a role for consumer patience as affecting competition. Our heuristic discussion above suggests that more intense competition through more patient consumers can lower the strategic cost of information sharing and encourage such practices. Proposition 4 illustrate this result in the limit – when  $\delta_c = 1$  the market is at its most competitive level, holding  $s$  and  $\tau$  constant, and the strategic cost of information sharing can be as low as zero, ensuring that sharing information is an equilibrium in the one-shot information-sharing game.

### 3.3 Data and Empirical Strategy

#### 3.3.1 Data

I use data from a cross-sectional survey of agricultural traders in Madagascar, conducted by the International Food Policy Research Institute (IFPRI) and the Malagasy Ministry of Scientific Research (FOFIFA), and previously used by Fafchamps and Minten (1999, 2000). The survey was designed to be representative of traders along the entire food marketing chain – wholesalers, retailers, and

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<sup>31</sup>Of these, only Jappelli and Pagano (1993) and Gehrig and Stenbacka (2006) explicitly look at changes in the competition parameters to determine how they will affect information sharing. Jappelli and Pagano (1993) use a permanent cost disparity between the local monopolist and a potential entrant to provide exogenous variation in the incumbent’s market power. Gehrig and Stenbacka (2006) use the distribution of borrowers’ switching costs to model the degree of competition in a duopoly market.

assemblers, – whose main product traded was a local staple food.<sup>32</sup> Traders from three main agricultural areas (Fianarantsoa, Majunga, Antananarivo) were sampled and particular attention was paid to obtaining observations from both urban and rural communities. The survey was administered in two rounds - 850 traders were surveyed in the first round in May-August 1997 and 738 of those respondents were traced for a follow-up survey in September-November of the same year.<sup>33</sup> The dataset is unique in providing a rich set of measures on traders' information sharing practices, liquidity position, access to credit, reliance on formal institutions, contractual risk, and conflict resolution. Table B.1 presents definitions of relevant variables to be used in the estimation and Table B.6 presents summary statistics.

The business environment captured in the survey is representative of the type of settings that motivate our study. The data reveals that traders are exposed to contractual risk from both suppliers and customers – 31% of the second-round sample report receiving late or no payment from customers in the past twelve months and 21% report late or no delivery from suppliers for the same period. Only 2 of the 738 traders in the sample have resorted to formal means of contract enforcement such as the police or the courts.<sup>34</sup> Yet, the conflict resolution rate is 77% for the traders reporting issues with customers and 84% for those reporting issues with

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<sup>32</sup>For a more detailed discussion of the survey design and the sample composition, see Fafchamps and Minten (1999).

<sup>33</sup>The questionnaire from the first round gathered information on trader and firm characteristics while the questionnaire from the second round focused on the traders' relationships with customers, suppliers and other traders. The data used in this investigation is drawn from both rounds of the survey.

<sup>34</sup>The survey does not ask if traders resort to private enforcers, hence it cannot be determined if private enforcement is a feasible alternative that may be preferred to the use of information networks.

suppliers, suggesting that informal contract-enforcement mechanisms may be at work.<sup>35</sup> There is also evidence that traders do screen customers on the basis of past performance: among the 285 traders who were asked if delinquent customers will be refused credit from their other suppliers as well, 74.7% respond that at least some suppliers will stop extending credit and 24.9% report that most or all suppliers will do so; less than 1% of the traders state that they would sell on credit to a new customer. Furthermore, in a developing country context liquidity is likely to represent a sizeable hurdle to information sharing practices, which facilitates a test of the model's liquidity hypothesis.

I obtain data on the traders' information-sharing practices from a question that asks respondents about the frequency with which they talk to other traders about delinquent customers.<sup>36</sup> There is also information about the frequency of discussing the product quality of different suppliers. I choose to use only the question on discussions about customers because it is more likely to capture the exchange of information regarding contract performance. Specifically, the data indicate that there is less room for opportunistic breach of contract with respect to product quality – 84.5% of the traders report that they always check the supplier's product quality before purchase and another 12.5% of the traders report they do so often. Those traders who state that product quality varies a lot were asked to indicate the reason for this variation and none of the respondents attribute it to malfeasance on behalf

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<sup>35</sup>The conflict resolution rate is computed as the share of traders who resolved their contractual disputes with customers/suppliers.

<sup>36</sup>Fafchamps and Minten (1999) point out that by 'other traders' respondents understood 'other traders who operate in a manner similar to yours'. See Footnote 11 in Fafchamps and Minten (1999).



of suppliers.<sup>37</sup>

The question about traders' discussions of delinquent customers does not make it clear whether traders disclose information about their own customers or receive information from other firms. Case study evidence from other markets indicates that information sharing is based on reciprocity, so I assume that discussions about delinquent customers point to the existence of information sharing networks with two-way information flows. The question is directed only at those respondents who report having regular customers. This reduces our sample size to 344 observations. While it is not clear if traders communicate directly with their rivals, it is reasonable to assume that traders who want to withhold information from their rivals will not disclose it to anyone in that line of business. The possible answers to the question are 'daily', 'weekly', 'monthly', 'occasionally/less frequently than once a month', and 'never'. Only 3.2% of the traders report having such discussions at least weekly compared to 13.3% of traders who engage in such discussions at least monthly; 24% of the traders report that they never discuss customers with other traders.

Traders who report discussing delinquent customers at least once a month are coded as respondents who share information, giving rise to a binary dependent variable. This definition increases the likelihood that the transmission of information is timely and deliberate. Admittedly, the frequency of communication also depends on the frequency with which firms experience customer issues. In the sample 35.1%

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<sup>37</sup>Among the full sample of 738 traders, 147 report having received products of lower quality from their suppliers in the past 12 months. Among those, 50 respondents state that the quality of products they purchase varies at least somewhat, but none of those 50 respondents identifies cheating on behalf of the supplier as a cause for this variability. However, when asked why they think product quality varies a lot, only 3 out of the 738 respondents attribute this variation to manipulation on behalf of the suppliers.

of the firms who extend sales credit have not experienced late or no payment from customers in the past year. Under a binary specification of the dependent variables traders who face a significantly lower default rate may appear to be less likely to share information. To use the full information contained in the traders' responses I also report results from coding the dependent variable as categorical according to the reported frequency of information exchange.

Since information sharing is driven by exposure to contractual risk, I limit the sample to traders who extend sales credit.<sup>38</sup> I exclude traders who are non-Christian, a total of ten observations, because of the concerns that they may be part of closely-knit ethnic networks.<sup>39</sup> Traders from the regions Majunga Plaines and Majunga Hauts Plateaux are also dropped during the estimation procedure because of their limited representation in the sample, which causes collinearity issues. Finally, among the traders who state the number of competitors they have over their regular customers, I keep only those who have at least one competitor in order to exclude monopolies. I also keep those traders who respond that they do not know how many competitors they have. The final sample used in the estimation consists of 279 observations. Table B.1 presents definitions of all variables relevant to the discussion that follows and Table B.6 shows presents summary statistics.

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<sup>38</sup>Of the traders who are asked about their information sharing practices, 96.5% are selling on credit. Only 1 trader in the sample reports that he discusses customers with other traders but does not extend sales credit himself.

<sup>39</sup>Fafchamps and Minten (1999) note that the Malagasy society tends to be fairly homogeneous in terms of ethnicity and religion and respondents who identify as non-Christian could represent the few ethnic minorities in the country

### 3.3.2 Empirical Strategy

The theoretical model yields the unequivocal result that firms are more likely to share information if their rivals are liquid, but it is ambiguous about the impact of operating in a market with more intense competition. In principle, one would like to use the liquidity prediction to test the model, and the correlation between information sharing and competition to gain insight of the relationship between the two, based on firm-level observational data. This suggests one would estimate a model of the form

$$y_i^* = \alpha_0 \cdot Liquidity_i + \alpha_1 \cdot Competition_i + \alpha_2 X_i + \epsilon_i \quad (3.3.1)$$

where

$$Y_i = 1 \quad \text{if } y_i^* > 0$$

$$Y_i = 0 \quad \text{if } y_i^* \leq 0$$

and  $y_i^* > 0$  indicates information sharing while  $y_i^* \leq 0$  – no information sharing;  $\epsilon_i \sim N(0, \sigma_\epsilon^2)$  and  $i = 1, 2, \dots, K$  indexes observations; *Liquidity* is a measure of the rival's liquidity position, *Competition* measures the intensity of competition in the market, and  $X$  is a vector of controls.

## Liquidity measures

Consistent estimation of  $\alpha_0$  requires that  $E[Liquidity_i \epsilon_i | X_i] = 0$ . Again, in my model causality runs directly from liquidity to information sharing so this assumption is satisfied in the model. Furthermore, I would argue that for at least one of the liquidity measures discussed below, it is reasonable to assume that it is not correlated with  $\epsilon_i$ . Thus, I should be able to test the implication of the model that  $\alpha_0 > 0$ .

The dataset does not allow us to identify a trader's local competitors. Hence, I have no explicit information about their number or their liquidity position. Assuming that the model's predictions hold for more than one competitor and assuming that markets are homogeneous, I focus on identifying a proxy for the liquidity position of traders who operate in the respondent's market. I construct two such proxies – one set of liquidity measures (to be discussed below) uses *own* liquidity to proxy for market liquidity, and a second set of liquidity measures uses the *average* liquidity of traders in the same market. A market is defined as the intersection of main product traded and distribution category. With six products traded and 7 distribution categories, there are 42 possible markets although not all of them are represented in the sample. Restricting attention to markets with at least two observations, we are left with 27 markets in the sample. The average value of liquidity within a market is based on the liquidity measures of all traders in this market after excluding the observation at hand since we are mainly interested in obtaining information about the rivals' liquidity position. I will refer to this set of liquidity proxies as *average*

liquidity and to the former set of proxies – *own* liquidity.

The use of either proxy rests on the assumption that firms within a market are not too dissimilar in their liquidity positions. This assumption is reasonable if traders' liquidity positions are related to the characteristics of agricultural markets in Madagascar. For example, being able to rely on family members for credit requires that the trader's family is not employed in the same enterprise. The data shows that among the three broad trade categories (assemblers, wholesalers and retailers) assemblers are the most likely to have non-family members as employees and also the most likely to have more than three family members with jobs. The availability of own liquid funds and a credit network can also lead traders to self-select into markets with high or low volatility of earnings, or markets with high or low entry costs. For these reasons, I believe the assumption about traders' similar cost of capital is likely to be satisfied. In case this assumption is not satisfied for all traders, then the estimate of  $\alpha_0$  would provide a lower bound on the true value of  $\alpha_0$  as the model suggests that in non-homogeneous markets liquid firms are less likely to share information with their liquidity-constrained rivals.

To measure the liquidity position of each observation and create the proxies for the market liquidity, I construct two different liquidity scores, referred to as LS 1 and LS 2. The first liquidity score, LS 1, uses those variables that give us most confidence in their exogeneity – these are the dummy variable for being able to borrow from friends/family at the present if financial hardship arises and the categorical variables for number of family members or friends the trader can borrow from and number of family members with jobs. A more detailed description of

these variables is provided in Table B.2. The questions that produce these variables exclude the respondent's spouse from the definition of family and friends. Since we have one dummy variable and two categorical variables that range from 0 to 2, the maximum liquidity score is equal to 5 and its frequency distribution is presented in the first column of Table B.3.

Using LS 1, liquidity is exogenous if having a network of friends or family who are able to extend credit is uncorrelated with unobservable trader/firm characteristics that may also drive information sharing behavior. Ideally, this liquidity measure would be entirely driven by exogenous variation in family size, geographic proximity to family and friends, or area-specific characteristics that affect income levels and diversification of economic activities among the local population. However, we cannot rule out that the availability of a network of friends or family may be cultivated over time and is likely based on reciprocal relationships, which raises the concern that traders who have such networks may be more patient or may have an unobservable taste for cooperation.<sup>40</sup> Hence, I include a dummy variable equal to one if the trader reports discussing input or output prices with other traders and a dummy variable equal to one if the trader reports discussing the quality of suppliers' products with other traders.<sup>41</sup> Both variables may capture unobserved characteristics that affect the trader's propensity to cooperate with other traders.

For the second specification of the liquidity score, LS 2, I use variables that reflect the availability of personal funds - these are the dummy variables for possessing

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<sup>40</sup>For example, traders who expect to stay in the market/area for a longer period may be more likely to engage in reciprocal relationships with friends/family as well as local business rivals.

<sup>41</sup>Similar to the definition of the dependent variable, only traders reporting at least monthly discussions are coded as actively discussing prices or product quality.

a bank account, having another source of income (own or through spouse), reporting formal savings, reporting informal savings, and having access to overdraft facility (see Table B.4 for the resulting frequency distribution).<sup>42</sup> This liquidity score also ranges from 0 to 5 although none of the traders possesses a score above 3.

It should be noted that the dataset also provides information on variables that could proxy for the traders' ability to negotiate favorable payment terms with customers and suppliers in case of a liquidity crunch. The results from using these measures of liquidity are qualitatively the same as those reported for LS 1 and LS 2. I do not report them here because they are ambiguous in terms of their implications for the trader's liquidity position. For example, receiving supplier credit on a regular basis may indicate ability to obtain credit during a liquidity crunch but it may also indicate that the trader is liquidity constrained even in the absence of shocks.

Under LS 2, liquidity is exogenous if own liquid assets are uncorrelated with unobservables that affect information sharing behavior. This assumption is more contestable because traders' personal assets can be a by-product of the market in which they operate and unobservable market characteristics can affect both information sharing behavior and liquidity. Furthermore, information sharing may also affect traders' liquidity. As discussed below I include a set of controls capturing a number of market characteristics that should minimize the possible bias in  $\alpha_0$ .

I report results using both LS1 and LS 2 as alternative measures of liquidity.

When using own liquidity as a proxy for the rival's liquidity, the liquidity score of the

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<sup>42</sup>While the dataset also has information whether the trader has received formal bank credit in the past, I do not include this variable in the liquidity score because bank credit likely cannot be obtained quickly enough to cover unexpected cash outflows. Fewer than 10% of the traders in the final sample had applied for bank loan in the past.

current observation is used. While LS 1 is more likely to be exogenous and provide causal estimates, LS 2 is likely to capture market liquidity with less noise because it is a direct measure of the availability of personal funds. Table B.5 summarizes the distribution of the liquidity variables based on average market liquidity (for each of the two measures, LS 1 and LS 2).

### **Control variables**

Table B.7 provides a summary of all control variables included in the estimation of (3.3.1). To capture a large set of market characteristics that may affect market power and exposure to risk, I include controls for firm size (based on total sales and coded by the data collectors), firm age, trade category (e.g. wholesalers, assemblers or retailers), geographic region (or city, as a robustness check), capital location, main product traded, and access to a telephone. Market-level controls mitigate the potential omitted variables bias when using LS 2 and can also proxy for unobservable characteristics correlated with the level of competition. I also control for demographic characteristics such as sex, age, and education level.

Information sharing incentives are stronger when the firm is exposed to higher default risk. To control for exposure to risk, I first include categorical variables for the number of traders the respondent knows personally.<sup>43</sup> Traders with larger trade networks can disseminate and receive information about delinquent customers in a more timely manner and they can also anticipate that customers would be aware of the stronger reputation effects if they default to a well-connected trader.

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<sup>43</sup>Since Fafchamps and Minten report that the data is subject to considerable measurement error I recode some continuous variables as categorical.



Hence, traders with larger networks may face significantly lower default risk and communicate information about customers less frequently. Second, I control for the trader's percent of sales on credit. Credit sales reduce a potential omitted variable bias in the estimate of the liquidity measures – since liquidity may be positively correlated with credit sales, we can erroneously interpret a positive coefficient of the liquidity measure as a validation of the model, while in effect it may be driven by higher exposure to risk (since the latter provides a stronger incentive to engage in information sharing). As a robustness check, I also estimate (3.3.1) by restricting the sample to traders with credit sales between 15% and 50% and compare the results to those for the full sample.

I include discussing prices and discussing suppliers' product quality as proxies for unobserved market characteristics that may facilitate cooperation and information exchange in the market. As it will be evident from the discussion of the competition controls below, discussing prices does not suggest price collusion. Finally, I do not include number of competitors in the set of controls because the variable appears to be very noisy and does not have any meaningful impact on the regression results.

### **Competition measures**

I use three measures of competition to establish a correlation between information sharing and competition intensity. The most straight-forward measure, *Competition*, is a self-reported measure of the strength of competition the trader faces: *Competition* is equal to one if the trader responds that the level of compe-

tion in their market is high, and zero – if competition is reported to be low or moderate. To consistently estimate  $\alpha_1$  we need  $E[Competition_i \epsilon_i | X_i] = 0$ . This is satisfied in my model since causality runs directly from competition to information sharing. As already mentioned, a major distinction between my model and the previous literature is that I can identify a role for competition that does not generate a feedback effect of information sharing on competition. Nevertheless, the feedback effects pointed out by previous studies can also have a role in a real-world setting and can lead to a simultaneity bias in our estimates. For example, traders who share information may anticipate lower default rates and extend more sales credit, leading to more intense competition for customers. This potential endogeneity can be overcome if there is a suitable instrumental variable. Such an instrument must be i) correlated with *Competition*, ii) uncorrelated with  $\epsilon$  and iii) not included in  $X$ . Table B.8 shows the results of regressing *Competition* on a number of firm characteristics. It shows that variables such as having completed high school education, being more liquid as measured by LS 1, engaging in product processing as a secondary activity and having a large share of sales to regular customers are all associated with a lower propensity of reporting strong competition, so they satisfy i). None of the remaining firm characteristics, including the dummy for discussing prices, have significant coefficients. Number of competitors also does not have a significant effect on reported competition possibly because it is a very noisy measure of the true number of direct competitors.

How do we interpret the significant negative coefficients of product processing and share of regular customers? Product processing can add more variation in the

quality of the final product so it can be interpreted as indicating greater product differentiation. A larger share of regular customers could be associated with higher switching costs and/or a higher degree of product differentiation. Both variables may satisfy iii) because they are likely to affect information sharing only through competition. Furthermore, one can argue that they are uncorrelated with  $\epsilon$ , so ii) is satisfied too. However, they do not pass the tests for weak IV by Staiger and Stock (1997) and Stock and Yugo (2005). In the absence of stronger instruments, I estimate (3.3.1) to obtain the OLS (partial) correlation between self-reported competition intensity, given by *Compet* and information sharing.

As indicated by the results in Table B.8, the coefficients of sales to regular customers, and in column (6) those of product processing, are precisely estimated and consistent with the interpretation that these two variables capture to some extent the degree of switching costs and product differentiation in the market. For this reason, I include them as proxies for competition intensity. They are also less likely to be endogenous and subject to simultaneity bias from the feedback effect of information sharing on competition.<sup>44</sup> This allows us to test the implications of Corollary 2 – specifically, the corollary predicts that information sharing is more likely among traders who engage in product processing or have a high share of sales to regular customers because the latter are indicative of high switching and/or transportation costs, which raise the liquidity threshold. Because of concerns that self-reported competition may be endogenous and bias all coefficient estimates, I

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<sup>44</sup>This statement would not be valid if information sharing affects consumer switching costs. In the model switching costs are assumed to be exogenous and driven by factors, other than the choice of information-sharing regime.

add it to the regression separately from the preceding two competition proxies.

The results from Table B.8 also help us rule out variables that may be suspect of indicating collusive practices in the market. For example, discussing prices with other traders is shown to have no impact on the perception of competition intensity. This is consistent with the findings in Fafchamps and Minten (2002) who use this dataset to examine the impact of social capital on firm productivity and find no evidence that social capital is associated with collusion on prices.<sup>45</sup> In fact, the question that asks traders if they discuss prices with other traders does not distinguish between input and output prices. Since discussing suppliers' product quality is highly correlated with discussing prices, it is more plausible that traders discuss input prices. Therefore, the price discussion dummy cannot be interpreted as indicative of collusion.

Interestingly, firms with liquidity score LS 1 greater than 1 are significantly less likely to report strong competition (column 4), while our second and more explicit measure of liquidity, *LS2*, does not have a significant effect (column 5). However, when I use a liquidity dummy equal to one when  $LS1 > 2$  (not reported), this effect disappears – LS 1 is no longer significant (p-value = 0.265). Hence, it is possible that the significance of the LS 1 scores is due to the small number of observations in the omitted category, i.e. observations with LS 1 equal to or less than 1.

Finally, note that controlling for credit sales in (3.3.1) helps us reduce a potential omitted variable bias in the estimate of the impact of self-reported competition.

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<sup>45</sup>Fafchamps and Minten (2002) measure social capital in terms of number of traders known, number of family members in agricultural business and number of people the trader can borrow from and find that it has no significant impact on traders' profit margin.

Evidence from developing countries shows that market power and credit sales can be positively correlated due to enforcement concerns (McMillan and Woodruff, 1999) or negatively correlated if sales credit is used as a competitiveness tool (Fisman and Raturi, 2004; Van Horen, 2007; Fabbri and Klapper, 2008). Hence, competition may affect the percent of credit sales that a firm extends and, therefore, its exposure to risk and likelihood to share information. Since we are interested in the impact of competition ex-post, it is important to control for exposure to risk and the share of sales on credit is an adequate proxy.

## 3.4 Results

Unless specified otherwise, all regression results below report probit coefficients with robust standard errors and include controls for trader and market characteristics as listed in Table B.7.

### 3.4.1 The Impact of Competition

The raw correlation between the perceived intensity of competition and information sharing is 0.078 based on the responses of 377 traders. The correlation is positive, but not statistically significant. Table B.9 shows the partial correlation between the two after estimating 3.3.1. Column (1) shows the results of including only *Competition* and the main market and demographic controls listed in Table B.7. Column (2) adds the additional set of controls: % of sales on credit, competition proxies, and discussing prices and suppliers. Columns (3) - (6) each include a

different liquidity measure based on the two liquidity specifications, LS 1 and LS 2, and the two alternative proxies, own liquidity and average market liquidity. Across all columns the dummy variable for reporting strong competition has a positive and significant coefficient, indicating that traders who perceive their markets as more competitive are more likely to share information about delinquent customers. As mentioned before, this result has to be interpreted with caution due to possible simultaneity bias. If we believe that there is a feedback effect of information sharing on competition and *Competition* captures the ex-post level of competition, then this result would be consistent with the findings in Jappelli and Pagano (1993), Padilla and Pagano (1997), and Gehrig and Stenbacka (2006) that information sharing intensifies competition. Otherwise, the positive coefficient on *Competition* is consistent with the conjecture in our model that information sharing is more likely in ex-ante more competitive markets (if competition is driven by consumer patience).

The two objective competition measures, product processing and the percent of sales to regular customers, are included in columns (2) - (6). Product processing has the expected positive coefficient but is imprecisely estimated. The coefficient on sales to regular customers is negative and significant in columns (4) - (6), suggesting that traders with a higher share of sales to regular customers are less likely to share information. In line with the interpretation of this variable as indicating higher switching costs or greater product differentiation, this result is inconsistent with the model's predictions.

Among the coefficients for the trader and market characteristics, we obtain that semi-wholesalers and retailers with a fixed point of sale exhibit a higher propen-

sity to share information relative to wholesalers. Large and medium-sized firms as well as firms who have been in operation between 5 and 10 years and firms whose main product is beans or peanuts, relative to traders whose main product is rice (results for these variables are not reported for brevity), all exhibit a higher propensity to share information. The estimates also indicate that traders who share information about prices are significantly more likely to share information about delinquent customers. The coefficient on discussing prices is particularly large and significant at the 1% level. These results largely persist for the rest of the reported regressions.

### **3.4.2 The Impact of Liquidity**

In this subsection the emphasis is on the effect of the liquidity measures on information sharing. Table B.10 presents the estimates of the liquidity coefficients, based on several specifications of the liquidity variable. Column (1) lists the results from using only the main market and demographic characteristics. Columns (2) through (5) add alternative sets of controls: percent of credit sales, self-reported competition intensity, competition proxies, and discussing prices and suppliers. Column (6) presents the results when all above-mentioned controls are included. Finally, in column (7) I also control for the trader's beliefs that if other suppliers knew about the delinquency of a customer, they would not extend credit to this customer. This question is asked of only a subsample of the traders, which reduces the sample size to 198 observations. Hence, we report the results from including this control separately.

Panel A presents the coefficient estimates of own liquidity, as measured by liquidity score 1, as a categorical variable. Recall that LS 1 captures traders' ability to borrow from friends and family and own liquidity is assumed to proxy for the liquidity of the trader's rival. Observations with liquidity scores of 0 are grouped together with those who have liquidity scores of 1 and constitute the omitted category. Relative to this group, the coefficient on observations with liquidity scores of 2 is negative and significant. The coefficients for all other categories are insignificant. Overall, the results in Panel A do not present a clear picture of the role of liquidity on information sharing. This may be due to the fact that the omitted category, traders with liquidity scores of 1 or less, is too small (only 21 observations) to produce informative results. Therefore, in Panel C we replace the category dummies with a single dummy variable that seeks to more clearly distinguish liquid from illiquid firms based on LS 1.

Panel B again presents the results from using own liquidity as a proxy for the rival's liquidity position, but uses liquidity score 2 to measure liquidity. In columns (1) - (4) traders with liquidity scores of 2 or 3 are significantly more likely to share information relative to traders with liquidity scores equal to 0. This result persists upon the inclusion of all control variables (column 6) and is consistent with the model's prediction. When we include the control for whether the trader believes a delinquent customer will be refused credit by most traders, the coefficients on the liquidity score dummies change in a nontrivial way: traders with  $LS\ 2 = 1$  are now significantly less likely to share information relative to the more liquidity constrained group of traders with  $LS\ 2 = 0$  while the coefficients for having a score of 2 or 3



remain positive but insignificant.

In Panels C and D, we replace the category dummies for own liquidity with one aggregate indicator. In Panel C, we use a dummy equal to 1 if LS 1 is greater than two. The chosen cutoff point treats the bottom one-third (33.55%) of the traders as operating in liquidity-constrained markets. Admittedly, the cutoff point is arbitrary chosen but a cutoff of 3 or 4 leads to qualitatively identical results, except that in some specifications a cutoff of 3 leads to very imprecise, albeit positive, estimates of the liquidity dummy coefficient. In Panel D we use a dummy equal to 1 if  $LS\ 2 > 1$  (see Table B.10). This procedure again treats roughly the bottom one-third (26.56%) of the traders as facing liquidity constraints in their markets. Again, the model predicts a positive coefficient for the so-constructed liquidity indicator variables. In both panels C and D, the liquidity estimates are consistently positive and significant throughout the inclusion of all control variables (columns 1 - 7), as predicted by the model. When controlling for discussing prices and suppliers, the liquidity coefficients in both panels increase in magnitude and become more precisely estimated, possibly due the fact that discussing prices explains a large part of the variation that was not picked up by liquidity. In column (7) I again add a dummy variable equal to one if the trader believes a delinquent customer will be refused credit by most traders. With this additional control, the liquidity coefficients almost do not change their value and standard error, giving us more confidence in the stability of the results. In results that are suppressed in this table for conciseness, it can be seen that in column (7) the coefficient on product processing becomes large, positive and significant at the 1% level – this estimate is consistent

with the interpretation that product processing as a secondary activity reflects a larger degree of product differentiation, which was shown to relax competition and facilitate information sharing.

In Panels E and F, I use average market liquidity as a proxy for the rival's liquidity. In Panel E, the liquidity variable is based on liquidity score 1, while in Panel F – on liquidity score 2. Higher average liquidity scores indicate higher average liquidity in the trader's market. In Panel E the coefficient on liquidity is positive and significant upon the inclusion of all controls (columns 6 and 7). In Panel F, the coefficient on liquidity is positive and significant across all columns. Hence, the results using average market liquidity as a proxy are consistent with the results that rely on own liquidity (Panels A - D). Together, these results present consistent evidence that rivals' liquidity has a positive effect on traders' propensity to share information. Results, based on liquidity score 1 are arguably providing causal estimates, but they are also less precisely estimated, which is consistent with our conjecture that they are a more noisy measure of the rival's liquidity position.

### **Robustness checks**

Table B.11 presents several robustness checks for the full set of liquidity measures used in Table B.10. Column (1) replicates column (6) from Table B.10. Column (2) replaces the region fixed effects with city fixed effects. The resulting changes in the estimates are negligible across all liquidity measures. I use region fixed effects in the main specification because fewer observations are dropped during the estimation process. In column (3) I restrict the sample to include only firms with

credit sales between 15% and 50% of total sales.<sup>46</sup> This reduces the variation in exposure to risk through credit sales and still includes about 60% of the sample. Again, there are no qualitative changes in the results when compared to column (1). Column (4) limits the sample to only those traders who have experienced late or no payment from customers in the past twelve months, which I would refer to as customer default. This reduces the sample to 152 observations but ensures that we are only looking at markets where cheating is known to occur – hence, some of the unobserved variation in default risk is reduced. The set of measures using own liquidity as a proxy (panels A - D) preserve their signs and significance levels compared to the baseline results. The measures using average market liquidity (panels E and F) lose significance but remain positive. Overall, these robustness checks confirm that our results are stable across different specifications, with the exception of average liquidity measures which become insignificant when restricting the sample to traders who have experienced customer default.

Table B.12 presents the results from estimating an ordered probit model where the dependent variable is categorical and reflects the frequency with which traders exchange information about customers. The dependent variable takes on discrete values from 1 to 5 where a value of 1 indicates the trader never discusses customers and 5 indicates that the trader discusses customers daily. Columns (1) - (2) report results using the own liquidity proxies and columns (3) - (4) show results for the average market liquidity proxies. This specification of the dependent variable is much less informative. The only significant predictors of the frequency of the information

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<sup>46</sup>During the estimation, certain controls were dropped given the smaller sample size.

exchange are the dummies for discussing prices and being a large firm – their signs are consistent with the probit results. The liquidity coefficient is positive but not significant for the own liquidity proxy using LS 1 and for the average market liquidity proxy based on LS 2. Again, this is consistent with the prediction of the model and with the wider set of results presented in Tables B.10 and B.11.

In summary, the results in Tables B.10 and B.11 suggest that firms operating in liquid markets are more likely to share information about delinquent customers, as proposed by the model. This result is conditional on the validity of the two sets of proxies of rival’s liquidity – own liquidity and average market liquidity. The estimates are robust to the inclusion of various controls and to the use of various estimation specifications and liquidity measures. Since the first specification of the liquidity score can be credibly viewed as exogenous, the positive estimate of  $\alpha_0$  implies that liquidity has a positive causal effect on information sharing.

### **Marginal effects**

To get a better idea about the magnitude of the effect of liquidity, I compute the marginal effects of the two liquidity measures. The baseline specification is based on column (6) of Table B.10. For ease of interpretation, the liquidity proxy based on own liquidity uses liquidity dummies as defined in Table B.10 instead of indicator variables for the underlying categorical liquidity variable. Because most of the explanatory variables are binary estimating marginal effects at the mean values is not very informative. Therefore, I compute the average marginal effects

(see Table B.13).<sup>47</sup> The probability of information sharing is on average 9.7 points higher for liquid firms, if liquidity is defined in terms of ability to borrow from friends and family (i.e., based on the liquidity dummy using LS 1), and 13 points higher if liquidity is measured by personal funds (i.e., using LS 2). Using average market liquidity as a proxy, we find that the probability of information sharing is on average 8.6 points higher for each 1 point increase in the liquidity score of the market as measured by LS 1 and 17.3 points higher for each 1 point increase in the liquidity score of the market as measured by LS 2. All reported marginal effects are significant at the 10% level. These estimates indicate non-trivial changes in the probability that a trader would share information about delinquent customers if that trader operates in a liquid market.

### 3.5 Conclusion

Inter-firm information sharing is of key importance in developing and transition economies where reliance on formal contracting institutions is limited. The transmission of information about defectors helps firms screen out bad risks and reduce their exposure to contractual risk. At the same time, liquidity constraints are a common characteristics of economies with weak contract enforcement institutions and imperfect capital markets. In this study I derive a causal relationship between liquidity and information sharing and offer a systematic investigation into why inter-firm information sharing practices emerge in some markets and not in

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<sup>47</sup>The marginal effect for each observation is computed using the user-written Stata command *-margeff-*.

others.

Competition is commonly perceived as the main impediment to voluntary information exchange. I have shown that the presence of competition does not necessarily create barriers to information sharing. Second, I have identified consumer patience as a market characteristic, which intensifies market competition and encourages information sharing behavior. Third, this study sheds light on the importance of liquidity in the decision of rival firms to share information. The model suggests that markets populated by liquid firms are more likely to exhibit information-sharing networks. Using a relatively unexploited dataset on the information sharing practices of agricultural traders in Madagascar, I find support for this hypothesis, based on two alternative measures of liquidity. An important policy implication of this result is that improved access to low-cost credit can foster the formation of information-sharing networks and mitigate problems of contract breach.

I have limited attention to information sharing agreements between two rival firms in order to focus on the determinants of the strategic cost of information sharing. A natural extension of the research question would be to consider larger coalitions where each firm has one or more local rivals but does not face competition from the rest of the coalition members. In those cases the timing of information revelation becomes relevant because the informed firms may reveal information only after their rival has been exposed to the risk of cheating. Furthermore, as originally pointed out by Pagano and Jappelli (1993), an information sharing coalition can be a ‘natural monopoly’ – the returns from participating in the coalition increase as

more firms join in. These are two important features that are outside the scope of this study but merit further investigation within the context of the model at hand.

Another important component of this line of research is to perform a more rigorous test of the causal effect of competition intensity on information sharing. The lack of suitable instruments limits my ability to establish causality using observational data. The developments in the literature on information sharing in credit markets clearly show that empirical work in this area lags behind its theoretical counterpart. Brown and Zehnder (2008) make a significant contribution to this area by using an experimental setting that allows them to distinguish the impact of competition from the impact of default risk on lenders' incentives to pool information. The study of information sharing among firms can benefit tremendously from a similar experimental approach, given the paucity of observational data on information-sharing practices.

# Appendix A

## Appendix to Chapter 2

### A.1 Proofs

#### A.1.1 Proof of Proposition 1

*Proof.* Using the specification of the price strategies and value functions in terms of the state variable,  $x_t$ , we find the optimal price strategies,  $p_{nt}$ , and the resulting distribution of the market. We then show that when consumers are very patient prices are independent of firms' market shares and the market converges to the proposed equilibrium for all values of  $x_t$  in just one period. We proceed to find  $p_{ot}$  and the resulting mass of customers who switch in equilibrium. Finally, we determine the minimum value of exit costs that ensure that the proposed prices constitute an equilibrium in pure-strategies and show that within  $x_m, 1 - x_m$  neither firm has a profitable deviation given the proposed equilibrium prices. Without loss of generality, in the exposition that follows we normalize marginal costs to zero.



First we specify the firms' problem in period  $t$  by assuming that  $x_t$  is in some middle range,  $(x_m, 1 - x_m)$ , such that both firms poach:  $q_{ij} > 0$ . The relevant value functions are given by:

$$\begin{aligned}
V^A(x_t) = \max_{p_{nt}^A} \max \left( \frac{(\tau + s + p_{nt}^B)^2}{8\tau}, (\tau + s + p_{nt}^B - 2tx_t) x_t \right) & \quad (\text{A.1.1}) \\
+ p_{nt}^A \cdot \left( \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - p_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} + \frac{3\tau - s - p_{nt}^A}{4\tau} - x_t \right) \\
+ \delta_f \left( \alpha + \beta \cdot \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - p_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} \right. \\
\left. + \gamma \left( \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - p_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} \right)^2 \right)
\end{aligned}$$

$$\begin{aligned}
V^B(x_t) = \max_{p_{nt}^B} \max \left( \frac{(\tau + s + p_{nt}^A)^2}{8\tau}, (s + p_{nt}^A + 2\tau x_t - \tau)(1 - x_t) \right) & \quad (\text{A.1.2}) \\
+ p_{nt}^B \cdot \left( \frac{\tau(1 - \delta_c) - \delta_c a - \delta_c b + p_{nt}^A - p_{nt}^B}{2\tau - 2\tau\delta_c - \delta_c b} x_t - \frac{\tau + s + p_{nt}^B}{4\tau} \right) \\
+ \delta_f \left( \alpha + \beta \cdot \frac{\tau(1 - \delta_c) - \delta_c a - \delta_c b + p_{nt}^A - p_{nt}^B}{2\tau - 2\tau\delta_c - \delta_c b} \right. \\
\left. + \gamma \left( \frac{\tau(1 - \delta_c) - \delta_c a - \delta_c b + p_{nt}^A - p_{nt}^B}{2\tau - 2\tau\delta_c - \delta_c b} \right)^2 \right)
\end{aligned}$$

The corresponding best response functions are:

$$\begin{aligned}
p_{nt}^A(p_{nt}^B) &= (8\tau(2\tau - 2\tau\delta_c - \delta_cb) + 2(2\tau - 2\tau\delta_c - \delta_cb)^2 - 8\tau\delta_f\gamma)^{-1} \quad (\text{A.1.3}) \\
&\times \left[ (4\tau(2\tau - 2\tau\delta_c - \delta_cb) - 8\tau\delta_f\gamma) (\tau(1 - \delta_c) + \delta_ca + p_{nt}^B) \right. \\
&\quad + (2\tau - 2\tau\delta_c - \delta_cb)^2(3\tau - s - 4\tau x_t) \\
&\quad \left. - 4\tau(2\tau - 2\tau\delta_c - \delta_cb)\delta_f\beta \right]
\end{aligned}$$

$$\begin{aligned}
p_{nt}^B(p_{nt}^A) &= (8\tau(2\tau - 2\tau\delta_c - \delta_cb) + 2(2\tau - 2\tau\delta_c - \delta_cb)^2 - 8\tau\delta_f\gamma)^{-1} \quad (\text{A.1.4}) \\
&\times \left[ (4\tau(2\tau - 2\tau\delta_c - \delta_cb) - 8\tau\delta_f\gamma) (\tau(1 - \delta_c) - \delta_ca - \delta_cb + p_{nt}^A) \right. \\
&\quad + (2\tau - 2\tau\delta_c - \delta_cb)^2(4\tau x_t - \tau - s) \\
&\quad \left. - 4\tau(2\tau - 2\tau\delta_c - \delta_cb)\delta_f\beta \right]
\end{aligned}$$

The optimal price strategies are given by:

$$\begin{aligned}
p_{nt}^A = \frac{1}{D} & \left[ \left( 2(6\tau - 2\tau\delta_c - \delta_cb)(2\tau - 2\tau\delta_c - \delta_cb) - 8\tau\delta_f\gamma \right) \right. & (A.1.5) \\
& \times \left( (2\tau - 2\tau\delta_c - \delta_cb) \left[ 10\tau^2(1 - \delta_c) + 4\tau\delta_ca - 3\tau\delta_cb \right. \right. \\
& \quad \left. \left. - 4\tau(2\tau - 2\tau\delta_c - \delta_cb)x_t \right] - 4\tau\delta_f\beta(2\tau - 2\tau\delta_c - \delta_cb) \right. \\
& \quad \left. \left. - (2\tau - 2\tau\delta_c - \delta_cb)^2s - 8\tau\delta_f\gamma(\tau(1 - \delta_c) + \delta_ca) \right) \right. \\
& + \left( 4\tau(2\tau - 2\tau\delta_c - \delta_cb) - 8\tau\delta_f\gamma \right) \\
& \times \left( (2\tau - 2\tau\delta_c - \delta_cb) \left[ 2\tau^2(1 - \delta_c) - 4\tau\delta_ca - 3\tau\delta_cb \right. \right. \\
& \quad \left. \left. + 4\tau(2\tau - 2\tau\delta_c - \delta_cb)x_t \right] - 4\tau\delta_f\beta(2\tau - 2\tau\delta_c - \delta_cb) \right. \\
& \quad \left. \left. - (2\tau - 2\tau\delta_c - \delta_cb)^2s - 8\tau\delta_f\gamma(\tau(1 - \delta_c) - \delta_ca - \delta_cb) \right) \right]
\end{aligned}$$

$$\begin{aligned}
p_{nt}^B = \frac{1}{D} & \left[ \left( 2(6\tau - 2\tau\delta_c - \delta_cb)(2\tau - 2\tau\delta_c - \delta_cb) - 8\tau\delta_f\gamma \right) \right. \\
& \times \left( (2\tau - 2\tau\delta_c - \delta_cb)[2\tau^2(1 - \delta_c) - 4\tau\delta_ca - 3\tau\delta_cb \right. \\
& \quad + 4\tau(2\tau - 2\tau\delta_c - \delta_cb)x_t] - 4\tau\delta_f\beta(2\tau - 2\tau\delta_c - \delta_cb) \\
& \quad \left. - (2\tau - 2\tau\delta_c - \delta_cb)^2s - 8\tau\delta_f\gamma(\tau(1 - \delta_c) - \delta_ca - \delta_cb) \right) \\
& + \left( 4\tau(2\tau - 2\tau\delta_c - \delta_cb) - 8\tau\delta_f\gamma \right) \\
& \times \left( (2\tau - 2\tau\delta_c - \delta_cb) \left[ 10\tau^2(1 - \delta_c) + 4\tau\delta_ca - 3\tau\delta_cb \right. \right. \\
& \quad \left. - 4\tau(2\tau - 2\tau\delta_c - \delta_cb)x_t \right] - 4\tau\delta_f\beta(2\tau - 2\tau\delta_c - \delta_cb) \\
& \quad \left. - (2\tau - 2\tau\delta_c - \delta_cb)^2s - 8\tau\delta_f\gamma(\tau(1 - \delta_c) + \delta_ca) \right) \left. \right]
\end{aligned} \tag{A.1.6}$$

where

$$\begin{aligned}
D = & ((16\tau - 4\tau\delta_c - 2\delta_cb)(2\tau - 2\tau\delta_c - \delta_cb) - 16\tau\delta_f\gamma) \\
& \times (2(4\tau - 2\tau\delta_c - \delta_cb)(2\tau - 2\tau\delta_c - \delta_cb))
\end{aligned}$$

Using  $p_{nt}^A - p_{nt}^B = a + bx_t$ , we can derive  $a$  and  $b$  based on the optimal price strategies shown above. We find that

$$b = \frac{-8\tau}{F}(2\tau - 2\tau\delta_c - \delta_cb)^2 \tag{A.1.7}$$

$$a = \frac{8\tau}{F}((\tau(1 - \delta_c) + \delta_ca)(2\tau - 2\tau\delta_c - \delta_cb) - \delta_f\gamma(2\delta_ca + \delta_cb)) \tag{A.1.8}$$

where  $F = ((16\tau - 4\tau\delta_c - 2\delta_cb)(2\tau - 2\tau\delta_c - \delta_cb) - 16\tau\delta_f\gamma)$ .

From (A.1.7) and (A.1.8) we can establish that

$$a = -b/2 \tag{A.1.9}$$

Using  $p_{nt}^A = e + fx_t$  we can also derive  $e$  and  $f$  as functions of  $b$ :

$$f = \frac{-2\tau(2\tau - 2\tau\delta_c - \delta_cb)^2}{(8\tau - 2\tau\delta_c - \delta_cb)(2\tau - 2\tau\delta_c - \delta_cb) - 8\tau\delta_f\gamma} = \frac{b}{2} \tag{A.1.10}$$

$$e = \frac{2\tau^2(1 - \delta_c) + 4\tau(1 - \delta_c) - 3\delta_cb - 4\tau\delta_f\beta - 4\tau\delta_f\gamma - (2\tau - 2\tau\delta_c - \delta_cb)s}{2(4\tau - 2\tau\delta_c - \delta_cb)} - \frac{b}{4} \tag{A.1.11}$$

To identify  $\alpha, \beta, \gamma$  we use the prespecified quadratic functions for  $V^A(x_t)$  and  $V^B(x_t)$  and the affine functions for  $p_{nt}^A$  and  $p_{nt}^B$ :

$$\begin{aligned} & \alpha + \beta x_t + \gamma x_t^2 \tag{A.1.12} \\ &= \frac{(\tau + s + e - a + (f - b)x_t)^2}{8\tau} + \frac{e + fx_t}{4\tau(2\tau - 2\tau\delta_c - \delta_cb)} \left( 10\tau^2(1 - \delta_c) \right. \\ & \quad \left. + 4\tau\delta_ca - 3\tau\delta_cb - (2\tau - 2\tau\delta_c - \delta_cb)s - 4\tau(2\tau - 2\tau\delta_c - \delta_cb)x_t \right. \\ & \quad \left. + 4\tau(e - a + (f - b)x_t) - (6\tau - 2\tau\delta_c - \delta_cb)(e + fx_t) \right) \\ & \quad + \delta_f \left( \alpha + \beta \cdot \frac{\tau(1 - \delta_c) + \delta_ca - a - bx_t}{2\tau - 2\tau\delta_c - \delta_cb} + \gamma \left( \frac{\tau(1 - \delta_c) + \delta_ca - a - bx_t}{2\tau - 2\tau\delta_c - \delta_cb} \right)^2 \right) \end{aligned}$$

Rearranging and matching the terms, we obtain the expressions for  $\gamma$  and  $\beta$ :

$$\gamma = -\frac{b^2(2\tau - 2\tau\delta_c - \delta_cb)(18\tau - 2\tau\delta_c - \delta_cb) + 16\tau b(2\tau - 2\tau\delta_c - \delta_cb)^2}{32\tau((2\tau - 2\tau\delta_c - \delta_cb)^2 - \delta_fb^2)} \quad (\text{A.1.13})$$

$$\begin{aligned} \beta &= \frac{(\tau + s + e - a)(f - b)}{4\tau} \quad (\text{A.1.14}) \\ &+ \frac{e(-4\tau(2\tau - 2\tau\delta_c - \delta_cb) + 4\tau(f - b) - f(6\tau - 2\tau\delta_c - \delta_cb))}{4\tau(2\tau - 2\tau\delta_c - \delta_cb)} \\ &+ \frac{f(10\tau^2(1 - \delta_c) + 4\tau\delta_ca - 3\tau\delta_cb - (2\tau - 2\tau\delta_c - \delta_cb)s)}{4\tau(2\tau - 2\tau\delta_c - \delta_cb)} \\ &+ \frac{f(4\tau(e - a) - e(6\tau - 2\tau\delta_c - \delta_cb))}{4\tau(2\tau - 2\tau\delta_c - \delta_cb)} \\ &+ \frac{\delta_fb\beta}{2\tau - 2\tau\delta_c - \delta_cb} + \frac{2b(\tau(1 - \delta_c) + \delta_ca - a)}{(2\tau - 2\tau\delta_c - \delta_cb)^2} \end{aligned}$$

Plugging  $\gamma$  in (A.1.7) we can characterize  $b$ :

$$\begin{aligned} &[4b(8\tau - 2\tau\delta_c - \delta_cb) + 16\tau(2\tau - 2\tau\delta_c - \delta_cb)][(2\tau - 2\tau\delta_c - \delta_cb)^2 - \delta_fb^2] \\ &+ \delta_fb^3(18\tau - 2\tau\delta_c - \delta_cb) + 16\tau\delta_fb^2(2\tau - 2\tau\delta_c - \delta_cb) = 0 \quad (\text{A.1.15}) \end{aligned}$$

This equation is independent of  $s$  and if we normalize  $\tau = 1$ , it is equivalent to the one in Villas-Boas (1999).<sup>1</sup> Following the approach in Villas-Boas's paper, we let  $y = (2\tau - 2\tau\delta_c - \delta_cb)/b$  and rewrite (A.1.15) in terms of  $y$ . For  $\delta_c \rightarrow 1$  this equation reduces to

$$2y^3 + 3y^2 - \delta_f = 0 \quad (\text{A.1.16})$$

For  $\delta_f \in (0, 1)$  the equation above has three roots in the intervals  $(-3/2, 1)$ ,  $(-1, 0)$  and  $(0, 1/2)$ . The appropriate solution must also satisfy the second-order conditions

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<sup>1</sup>Equation A15 on pg. 626

for each firm, which are:

$$-8\tau(2\tau - 2\tau\delta_c - \delta_cb) - 2(2\tau - 2\tau\delta_c - \delta_cb)^2 + 8\tau\delta_f\gamma < 0 \quad (\text{A.1.17})$$

Rewriting this expression in terms of  $C = (2\tau - 2\tau\delta_c - \delta_cb)$ , we note that the second-order conditions are satisfied when  $\gamma < (4\tau C + C^2)/(4\tau\delta_f)$ . Rewriting (A.1.13) in terms of  $C$ , we get  $\gamma = -(b^2 C(16\tau + C) + 16\tau C^2 b)/(32\tau(C^2 - \delta_f b^2))$ . Then, we can show that the condition  $\gamma < (4\tau C + C^2)/(4\tau\delta_f)$  converges to  $2y^2 + \delta_f y - \delta_f > 0$  as  $\delta_c \rightarrow 1$ . Among the three possible ranges for  $y$ , the second-order conditions are satisfied only when  $y \in (-3/2, -1)$ . Also,  $y$  increases in  $\delta_f$  and  $y \rightarrow -1$  as  $\delta_f \rightarrow 1$ .

From  $y \in (-3/2, -1)$  we can see that for  $\delta_c \rightarrow 1$  the coefficient  $b$  must be negative. Furthermore,  $\partial b/\partial\delta_c < 0$ , and  $b \rightarrow 0$  as  $\delta_c \rightarrow 1$ .

Using the fact that  $b \rightarrow 0$  as  $\delta_c \rightarrow 1$ , it can also be seen that  $a$ ,  $e$ ,  $f$ ,  $\beta$  and  $\gamma$  all converge to zero as well. Therefore,  $p_{nt}$  converges to zero or marginal cost whenever  $c > 0$ . Obtaining the results for  $p_{ot}$ ,  $\hat{q}_{ii}$  and  $q_{ij}$  is straightforward after substituting  $p_{nt}^i$  in the appropriate expressions. We just note that when  $c > 0$ ,  $p_{ot}^i(p_{nt}^j) = (c + \tau + s + p_{nt}^j)/2$  and  $\hat{q}_{ii}(p_{nt}^j) = (c + \tau + s + p_{nt}^j)/(4\tau)$ .

From  $a = b/2$  and  $x_{t+1} = (\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - p_{nt}^A)/(2\tau - 2\tau\delta_c - \delta_cb)$  we can see that convergence to steady state occurs according to

$$x_{t+1} - \frac{1}{2} = \frac{-b}{2\tau - 2\tau\delta_c - \delta_cb} \left( x_t - \frac{1}{2} \right) \quad (\text{A.1.18})$$

Since  $-b/(2\tau - 2\tau\delta_c - \delta_cb) = y^{-1}$  and  $y \in (-3/2, -1)$ , it is clear that convergence

is monotonic and becomes infinitely slow when  $\delta_f \rightarrow 1$ .

We now find the limits of the poaching region  $(x_m, 1 - x_m)$  by looking for the range of  $x_t$ , within which neither firm has a profitable deviation in a price strategy that does not attract the rival's previous customers. Normalizing marginal cost to zero again, consider deviations for firm A such that it does not poach ( $q_{BA} = 0$ ). Therefore, the introductory price is given by

$$\begin{aligned} \bar{p}_{nt}^A = \arg \max p_{nt}^A \cdot & \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - p_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} + \delta_f \alpha \\ & + \delta_f \beta \cdot \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - p_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} \\ & + \delta_f \gamma \left( \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - p_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} \right)^2 \end{aligned} \quad (\text{A.1.19})$$

The first-order condition is

$$\begin{aligned} & \frac{(2\tau - 2\tau\delta_c - \delta_c b)(\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - 2p_{nt}^A)}{2\tau - 2\tau\delta_c - \delta_c b} \\ & - \frac{\delta_f \beta}{2\tau - 2\tau\delta_c - \delta_c b} - 2\delta_f \gamma \left( \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - p_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} \right) = 0 \end{aligned} \quad (\text{A.1.20})$$

Firm A's best response function is

$$\begin{aligned} \bar{p}_{nt}^A(p_{nt}^B) = & \frac{2\tau - 2\tau\delta_c - \delta_c b - 2\delta_f \gamma}{2(2\tau - 2\tau\delta_c - \delta_c b - \delta_f \gamma)} (\tau(1 - \delta_c) + \delta_c a + p_{nt}^B) \\ & - \frac{2\tau - 2\tau\delta_c - \delta_c b}{2(2\tau - 2\tau\delta_c - \delta_c b - \delta_f \gamma)} \delta_f \beta \end{aligned} \quad (\text{A.1.21})$$



Therefore, firm A's deviation payoff is given by

$$\begin{aligned}
V^A(\bar{p}_{nt}^A) = & \bar{p}_{nt}^A \cdot \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - \bar{p}_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} + \delta_f \alpha \\
& + \delta_f \beta \cdot \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - \bar{p}_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} \\
& + \delta_f \gamma \left( \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - \bar{p}_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} \right)^2
\end{aligned} \tag{A.1.22}$$

The payoff from poaching is

$$\begin{aligned}
V^A(p_{nt}^A) = & p_{nt}^A \cdot \left( \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - p_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} + \frac{3\tau - s - p_{nt}^A}{4\tau} - x_t \right) \\
& + \delta_f \alpha + \delta_f \beta \cdot \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - p_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} \\
& + \delta_f \gamma \left( \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - p_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} \right)^2
\end{aligned} \tag{A.1.23}$$

Firm A will not deviate if  $x_t$  is such that the payoff from poaching is weakly greater than the deviation payoff, i.e.  $V^A(p_{nt}^A) \geq V^A(\bar{p}_{nt}^A)$ . After some regrouping and canceling of common terms this inequality reduces to

$$\begin{aligned}
& (p_{nt}^A - \bar{p}_{nt}^A) \cdot \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B}{2\tau - 2\tau\delta_c - \delta_c b} - \frac{(p_{nt}^A)^2}{2\tau - 2\tau\delta_c - \delta_c b} \\
& + p_{nt}^A \cdot \frac{3\tau - s - 4\tau x_t}{4\tau} - \frac{(p_{nt}^A)^2}{4\tau} - \delta_f \beta \frac{p_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} \\
& - 2\delta_f \gamma \frac{(\tau(1 - \delta_c) + \delta_c a + p_{nt}^B)(p_{nt}^A - \bar{p}_{nt}^A)}{(2\tau - 2\tau\delta_c - \delta_c b)^2} + \delta_f \gamma \frac{(p_{nt}^A)^2}{(2\tau - 2\tau\delta_c - \delta_c b)^2} \\
& \geq -\frac{(\bar{p}_{nt}^A)^2}{2\tau - 2\tau\delta_c - \delta_c b} - \delta_f \beta \frac{\bar{p}_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} + \delta_f \gamma \frac{(\bar{p}_{nt}^A)^2}{(2\tau - 2\tau\delta_c - \delta_c b)^2}
\end{aligned} \tag{A.1.24}$$

Using  $C = 2\tau - 2\tau\delta_c - \delta_cb$  and plugging in the best response functions

$$p_{nt}^A(p_{nt}^B) = \frac{(4\tau C - 8\tau\delta_f\gamma)(\tau(1 - \delta_c) + \delta_ca + p_{nt}^B) - 4\tau C\delta_f\beta + C^2(3\tau - s - 4\tau x_t)}{2(4\tau C + C^2 - 4\tau\delta_f\gamma)} \quad (\text{A.1.25})$$

and

$$\bar{p}_{nt}^A(p_{nt}^B) = \frac{(C - 2\delta_f\gamma)(\tau(1 - \delta_c) + \delta_ca + p_{nt}^B) - C\delta_f\beta}{2(C - 2\delta_f\gamma)} \quad (\text{A.1.26})$$

the inequality  $V^A(p_{nt}^A) \geq V^A(\bar{p}_{nt}^A)$  simplifies to

$$(4\tau C + C^2 - 4\tau\delta_f\gamma)(p_{nt}^A)^2 \geq (4\tau C - 4\tau\delta_f\gamma)(\bar{p}_{nt}^A)^2 \quad (\text{A.1.27})$$

From the second-order conditions in (A.1.17) we can see that  $4\tau C + C^2 - 4\tau\delta_f\gamma > 0$  and, therefore,  $4\tau C - 4\tau\delta_f\gamma > 0$  as well. Thus, the inequality above can be written as

$$(p_{nt}^A)\sqrt{4\tau C + C^2 - 4\tau\delta_f\gamma} \geq \bar{p}_{nt}^A\sqrt{4\tau C - 4\tau\delta_f\gamma}.$$

Let  $M = 4\tau C - 4\tau\delta_f\gamma$ . We can rewrite  $\bar{p}_{nt}^A$  in terms of  $p_{nt}^A$ :

$$\bar{p}_{nt}^A = \frac{M + C^2}{M}p_{nt}^A - \frac{C^2(3\tau - s - 4\tau x_t)}{2M} \quad (\text{A.1.28})$$

Using  $p_{nt}^A = e + fx_t$ , (A.1.27) can be stated as

$$\sqrt{M + C^2}(e + fx_t) \geq \sqrt{M} \left( \frac{M + C^2}{M}(e + fx_t) - \frac{C^2(3\tau - s - 4\tau x_t)}{2M} \right) \quad (\text{A.1.29})$$

from which we obtain the critical value for  $x_t$  such that firm A is strictly better off engaging in poaching:

$$x_t \leq 1 - x_m = \frac{2 \left( M + C^2 - \sqrt{M(M + C^2)} \right) e - C^2(3\tau - s)}{-2 \left( M + C^2 - \sqrt{M(M + C^2)} \right) f - 4\tau C^2} \quad (\text{A.1.30})$$

Thus, when  $x_t \leq 1 - x_m$  poaching is an equilibrium strategy for firm A and, by symmetry, when  $x_t \geq x_m$  poaching is an equilibrium strategy for firm B. As  $\delta_c \rightarrow 1$ ,  $e \rightarrow 0$  and  $f \rightarrow 0$ , so  $1 - x_m \rightarrow (3\tau - s)/(4\tau)$ . Note that  $x_m \rightarrow (\tau + s)/(4\tau)$  which is equal to the equilibrium level of  $\hat{q}_{AA}$ .

We also derive an alternative expression for  $1 - x_m$  because it will allow us to sign its derivative with respect to  $s$ , which is one of the results stated in Corollary 1. First, using  $p_{nt}^B = e - a + (f - b)x_t = (2e + b - bx_t)/b$  and rewriting  $\bar{p}_{nt}^A$  in terms of C we obtain

$$\bar{p}_{nt}^A = \frac{C(C - 2\delta_f\beta) + (C - 2\delta_f\gamma)(2e + b - bx_t) - 2\delta_f\gamma C}{4C - 4\delta_f\gamma} \quad (\text{A.1.31})$$

Rewriting again in terms by using  $M = 4\tau C - 4\tau\delta_f\gamma$

$$\bar{p}_{nt}^A = \frac{C(C - 2\delta_f\beta - 2\delta_f\gamma) + (C - 2\delta_f\gamma)(2e + b - bx_t)}{M/\tau} \quad (\text{A.1.32})$$

Then,  $(4\tau C + C^2 - 4\tau\delta_f\gamma)(p_{nt}^A)^2 \geq (4\tau C - 4\tau\delta_f\gamma)(\bar{p}_{nt}^A)^2$  becomes

$$\begin{aligned} & \sqrt{M + C^2} \left( e + \frac{b}{2}x_t \right) \\ & \geq \sqrt{M} \left( \frac{C(C - 2\delta_f\beta - 2\delta_f\gamma) + (C - 2\delta_f\gamma)(2e + b - bx_t)}{M/\tau} \right) \end{aligned} \quad (\text{A.1.33})$$

which is satisfied for

$$x_t \leq 1 - x_m = \frac{\tau C(C - 2\delta_f\beta - 2\delta_f\gamma) + \tau(C - 2\delta_f\gamma)(2e + b) - 2We}{b[W + \tau(C - 2\delta_f\gamma)]} \quad (\text{A.1.34})$$

where  $W = \sqrt{M(M + C^2)}/2$ .

There are two implicit assumptions used in the derivation of  $x_m$ . First, in setting up  $V^A(p_{nt}^A) \geq V^A(\bar{p}_{nt}^A)$  we assume that  $q_{BA}(p_{nt}^A) > 0$ , which is true for  $\frac{3\tau - s - (e + fx_t) - 4\tau x_t}{4\tau} > 0$ . This condition is satisfied for

$$x_t < \bar{x} = \frac{3\tau - s - e}{4\tau + f} \quad (\text{A.1.35})$$

As  $\delta_c \rightarrow 1$ ,  $e \rightarrow 0$  and  $f \rightarrow 0$ , so  $\bar{x} \rightarrow \frac{3\tau - s}{4\tau}$ . Second, we assume that  $q_{BA}(\bar{p}_{nt}^A) = 0$  which is true for  $\frac{3\tau - s - \bar{p}_{nt}^A - 4\tau x_t}{4\tau} \leq 0$ . Using the expression for  $\bar{p}_{nt}^A$  in terms of  $p_{nt}^A$  we obtain

$$x_t \geq \underline{x} = \frac{(2M + C^2)(3\tau - s) - 2(M + C^2)e}{(2M + C^2)4\tau + 2(M + C^2)f} \quad (\text{A.1.36})$$

As  $\delta_c \rightarrow 1$ ,  $\underline{x} \rightarrow \frac{3\tau - s}{4\tau}$ . For  $\underline{x} \leq x_t \leq \bar{x}$  poaching is feasible under  $p_{nt}^A$  and not feasible under  $\bar{p}_{nt}^A$ . Tedious algebra shows that  $1 - x_m \in (\underline{x}, \bar{x})$  and therefore, the analysis

above is relevant.

We now derive the minimum level of exit costs that ensures that a firm with a relatively small market share does not have a profitable deviation in raising its price and selling to switchers only. Suppose that in period  $\hat{t}$  firm A starts with  $x_{\hat{t}} = 0$  (profits from poaching are highest when the firm has no market share) and deviates from the proposed equilibrium by setting  $p_{n\hat{t}}^A > p_{n\hat{t}}^B$  while  $p_{n\hat{t}}^B \rightarrow 0$ . From Lemma 1 we know that for  $\delta_c \rightarrow 1$  a firm that sets a price above the rival's price does not make any sales to newcomers so  $x_{\hat{t}+1} = 0$ . Therefore, firm A will set  $p_{n\hat{t}}^A$  so as to maximize profits from switchers in period  $\hat{t}$ :

$$p_{n\hat{t}}^A = \arg \max p_{n\hat{t}}^A \cdot \frac{3\tau - s - p_{n\hat{t}}^A}{4\tau} \quad (\text{A.1.37})$$

$$= \frac{3\tau - s}{2} \quad (\text{A.1.38})$$

At this price, sales to switchers equal  $q_{BA,\hat{t}} = (3\tau - s)/(8\tau)$  and the maximum profit from poaching in period  $\hat{t}$  equals

$$\hat{\Pi}_{\hat{t}}^A = \frac{(3\tau - s)^2}{16\tau} \quad (\text{A.1.39})$$

The net present value of firm A's deviation is

$$\frac{(3\tau - s)^2}{16\tau} - E + \sum_{\sigma=2}^{\infty} \delta_f^{\sigma} \bar{\Pi} \quad (\text{A.1.40})$$

where  $E$  stands for exit costs and  $\bar{\Pi}$  indicates the per-period level of profits within the

poaching region, which is equal to  $(\tau + s)^2/(8\tau)$ . We also use  $\bar{\Pi}$  to designate profits in the period when the market transitions from  $(x_s, x_m)$  to  $(x_m, 1 - x_m)$  because we do not have a straightforward expression for profits when  $x_t \in (x_s, x_m)$  while  $\bar{\Pi}$  provides an upper bound on these profits, which slightly strengthens the minimum required value of exit costs. Comparing the payoff from a one-time deviation to the payoff from staying on the equilibrium path we can obtain the minimum level of exit costs that guarantees that firm A has no profitable deviation in not selling to newcomers:

$$\frac{(3\tau - s)^2}{16\tau} - E + \sum_{\sigma=2}^{\infty} \delta_f^\sigma \bar{\Pi} \leq \sum_{\sigma=1}^{\infty} \delta_f^\sigma \bar{\Pi} \quad (\text{A.1.41})$$

$$E \geq \underline{E} = \frac{(3\tau - s)^2}{16\tau} - \delta_f \frac{(\tau + s)^2}{8\tau} \quad (\text{A.1.42})$$

□

## A.1.2 Proof of Corollary 1

*Proof.* 1.  $\partial p_n^i / \partial s < 0$  for  $\delta_c < 1$  and  $\partial p_n^i / \partial s = 0$  for  $\delta_c = 1$

We will show the proof for  $p_{nt}^A$ . Recall that  $p_{nt}^A = e + f x_t$  and  $f = b/2$ . From (A.1.15) we can see that  $b$  is independent of  $s$  and, therefore,  $f$  is independent of  $s$ . Therefore, to sign  $\partial p_{nt}^A / \partial s$  we need to find  $\partial e / \partial s$ . Note that  $e$  is also a function of  $\beta$  and the latter depends on  $s$  as well. In the proof of Proposition 1 we show that (A.1.14) and (A.1.11) jointly characterize  $\beta$  and  $e$ . We now explicitly solve for  $\beta$  and  $e$  and differentiate the resulting expression for  $e$  with

respect to  $s$ .<sup>2</sup> We obtain

$$\begin{aligned} \partial e/\partial s = & \left( -4C\delta_c b - 4C\delta_f b + 3\delta_f\delta_c b^2 + 8\tau C - 8\tau\delta_c C b - 8\tau C\delta_c \right. & (A.1.43) \\ & \left. - 22\tau\delta_f b + 14\tau\delta_f\delta_c b + 16\tau^2 - 16\tau^2\delta_c - 16\tau^2\delta_f + 16\tau^2\delta_c\delta_f \right)^{-1} \\ & \times [2(\delta_c b + C\delta_f b - \delta_f\delta_c b^2 - 2\tau C + 2\tau\delta_c C + 2\tau\delta_f b - 2\tau\delta_c\delta_f b)] \end{aligned}$$

and

$$\partial e/\partial s \rightarrow \frac{-(C - \delta_f b)}{4\tau(1 - \delta_f)} \quad (A.1.44)$$

as  $\delta_c \rightarrow 1$ . Note that  $C - \delta_f b > 0$  since  $b < 0$  and, therefore,  $\partial e/\partial s < 0$ .

In the limit  $\partial e/\partial s \rightarrow 0$ , since  $b \rightarrow 0$  and  $C \rightarrow 0$ .

2.  $\partial p_o^i/\partial s > 0$  Within the poaching region, firm A's optimal regular price is defined by  $p_{ot}^A(p_{nt}^B) = \frac{\tau + s + p_{nt}^B}{2}$ . Differentiating with respect to  $s$ , we obtain

$$\partial p_{ot}^A/\partial s = \frac{1 + \partial e/\partial s}{2} \quad (A.1.45)$$

Since  $\partial e/\partial s \rightarrow 0^-$ , we conclude that for  $\delta_c \rightarrow 1$ ,  $\partial p_{ot}^A/\partial s > 0$ .

3.  $\partial \hat{q}_{ii}/\partial s > 0$  and  $\hat{q}_{ii} \rightarrow \frac{1}{2}$  as  $s \rightarrow \tau$  The first part of this statement is a straightforward derivation of  $\partial \hat{q}_{ii}/\partial s$  from (2.2.13) and using the fact that  $\partial e/\partial s \rightarrow 0$ .

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<sup>2</sup>The explicit solutions for  $\beta$  and  $e$  were found using Mathematica 7.0. We do not include these solutions here because of their length. Files containing the exact solutions for  $\beta$  and  $e$  are available upon request.

To show that  $\hat{q}_{ii} \rightarrow \frac{1}{2}$  as  $s \rightarrow \tau$ , note that as  $p_n \rightarrow 0$  (or marginal cost),  $\hat{q}_{ii} \rightarrow (\tau + s)/4\tau$  which clearly converges to  $1/2$  as  $s \rightarrow \tau$ .

4.  $\partial x_m / \partial s > 0$  and  $x_m \rightarrow \frac{1}{2}$  as  $s \rightarrow \tau$

To sign the derivate  $\partial x_m / \partial s$  we use (A.1.34).

$$\frac{\partial(1 - x_m)}{\partial s} = \frac{-2\tau C \delta_f \left(\frac{\partial \beta}{\partial s}\right) + 2\tau(C - 2\delta_f \gamma) \left(\frac{\partial e}{\partial s}\right) - 2W \left(\frac{\partial e}{\partial s}\right)}{b[W + \tau(C - 2\delta_f \gamma)]} \quad (\text{A.1.46})$$

The denominator of this expression is negative because  $b < 0$  while  $W > 0$  and  $C - 2\delta_f \gamma > 0$ .

We will now show that for  $\delta_c \rightarrow 1$  the numerator of  $\partial(1 - x_m) / \partial s$  is positive.

From (A.1.11) we can derive

$$\frac{\partial e}{\partial s} = \frac{-8\tau \delta_f \left(\frac{\partial \beta}{\partial s}\right) - 2C}{4(2\tau + C)} \quad (\text{A.1.47})$$

which produces

$$\frac{\partial \beta}{\partial s} = \frac{2(C + 2\tau)}{4\tau \delta_f} \cdot \frac{\partial e}{\partial s} - \frac{C}{4\tau \delta_f} \quad (\text{A.1.48})$$

Plugging this expression into the numerator and using  $\partial e / \partial s \rightarrow -(C - \delta_f b) / (4\tau(1 - \delta_f))$ , the numerator of  $\partial(1 - x_m) / \partial s$  above can be expressed as



$$\begin{aligned}
& \frac{1}{2} \left[ (2C^2 + 8\tau C - 8\tau\delta_f\gamma - 4W) \left( \frac{-(C - \delta_fb)}{4\tau(1 - \delta_f)} \right) + C^2 \right] \tag{A.1.49} \\
&= \frac{1}{4\tau(1 - \delta_f)} \left[ -C^2(C - \delta_fb) - (M - 2W)(C - \delta_fb) + 2\tau C^2(1 - \delta_f) \right] \\
&\rightarrow \frac{1}{4\tau(1 - \delta_f)} \left[ -(M - 2W)(C - \delta_fb) + 2\tau C^2(1 - \delta_f) \right]
\end{aligned}$$

This expression is positive since  $M - 2W < 0$  and  $C - \delta_fb > 0$ . Therefore, the numerator of  $\partial(1 - x_m)/\partial s$  is positive. Combined with the fact that the denominator is negative, we obtain that  $\partial(1 - x_m)/\partial s < 0$ , or  $\partial x_m/\partial s > 0$ .

Showing that  $x_m \rightarrow \frac{1}{2}$  as  $s \rightarrow \tau$  is a straightforward application of the result that  $x_m \rightarrow (\tau + s)/(4\tau)$  as  $\delta_c \rightarrow 1$ .

□

### A.1.3 Proof of Corollary 2

*Proof.* Corollary 2 states that if switching costs are sufficiently high, the no-poaching region extends to the entire market, so the result from Proposition 2 regarding convergence to steady state applies automatically to all  $x_t \in [0, 1]$ . First, note that for  $(\tilde{x}_m, 1 - \tilde{x}_m)$  to extend to  $[0, 1]$ , it must be that  $\hat{q}_{ii}(p_{nt}^j) = 1$  and no deviations are profitable within  $(1 - \hat{q}_{BB}, \hat{q}_{AA})$ . The first condition holds when

$$s \geq (2 + \delta_c + 2\delta_f)\tau \tag{A.1.50}$$

The second condition is satisfied if  $\underline{x} = 0$ , or  $p_{nt}^A \leq 0$ , or  $\bar{p}_{nt}^A \leq 0$ . First, if

$\underline{x} = 0$ , then from (A.1.69) poaching is not feasible. In terms of  $s$ ,  $\underline{x} = 0$  whenever

$$s \geq \bar{s}_1 = \frac{(11 + 8\delta_f)(1 + \delta_f) - 10\delta_c(1 + \delta_f) - \delta_c^2(1 - 3\delta_f)}{(5 + \delta_c^2)(1 + \delta_f) - 2\delta_c(3 + \delta_f)}\tau \quad (\text{A.1.51})$$

Second,  $\bar{p}_{nt}^A \leq 0$  implies that poaching is not profitable so firm A will not deviate. This condition is satisfied when

$$s \geq \bar{s}_2 = \frac{7(1 - \delta_c)^2 + \delta_f(1 - \delta_c)(11 - 3\delta_c) + 4\delta_f^2 - 4(1 + \delta_f)(1 - \delta_c)^2x_t}{(1 + \delta_f)(1 + 4\delta_f + \delta_c^2) - 2\delta_c(1 + 3\delta_f)}\tau \quad (\text{A.1.52})$$

Finally,  $p_{nt}^A \leq 0$  ensures that the deviation price must be below zero in order for firm A to attract a positive mass of switchers and this condition is satisfied when

$$s \geq \bar{s}_3 = \frac{1 + \delta_f - \delta_c}{\delta_f}\tau \quad (\text{A.1.53})$$

Therefore, combining (A.1.50), (A.1.51), (A.1.52) and (A.1.53) we obtain sufficient conditions for  $(\tilde{x}_m, 1 - \tilde{x}_m)$  to cover the whole market:

$$s \geq \max((2 + \delta_c + 2\delta_f)\tau, \min(\bar{s}_1, \bar{s}_2, \bar{s}_3)) \quad (\text{A.1.54})$$

□

### A.1.4 Proof of Proposition 2

*Proof.* The firms' value functions within the no-poaching region were presented in (2.3.26) and (2.3.27). Taking the first-order conditions, we obtain the following best response functions:

$$p_{nt}^A(p_{nt}^B) = \frac{2\tau - 2\tau\delta_c - \delta_cb - 2\delta_f\gamma}{2(2\tau - 2\tau\delta_c - \delta_cb - \delta_f\gamma)} (\tau(1 - \delta_c) + \delta_ca + p_{nt}^B) \quad (\text{A.1.55})$$

$$- \frac{2\tau - 2\tau\delta_c - \delta_cb}{2(2\tau - 2\tau\delta_c - \delta_cb - \delta_f\gamma)} \delta_f\beta$$

$$p_{nt}^B(p_{nt}^A) = \frac{2\tau - 2\tau\delta_c - \delta_cb - 2\delta_f\gamma}{2(2\tau - 2\tau\delta_c - \delta_cb - \delta_f\gamma)} (\tau(1 - \delta_c) - \delta_ca - \delta_cb + p_{nt}^A) \quad (\text{A.1.56})$$

$$- \frac{2\tau - 2\tau\delta_c - \delta_cb}{2(2\tau - 2\tau\delta_c - \delta_cb - \delta_f\gamma)} \delta_f\beta$$

Let  $A = 2\tau - 2\tau\delta_c - \delta_cb - 2\delta_f\gamma$ ,  $B = 2\tau - 2\tau\delta_c - \delta_cb - \delta_f\gamma$  and  $C = 2\tau - 2\tau\delta_c - \delta_cb$ .

We solve for the optimal price strategies and express them in terms of these  $A$ ,  $B$  and  $C$ :

$$p_{nt}^A = \left[ 1 - \frac{A^2}{(2B)^2} \right]^{-1} \times \left( \frac{A^2}{(2B)^2} (\tau(1 - \delta_c) - \delta_ca - \delta_cb) - \frac{A \cdot C}{(2B)^2} \delta_f\beta \right. \quad (\text{A.1.57})$$

$$\left. + \frac{A}{2B} (\tau(1 - \delta_c) + \delta_ca) - \frac{C}{2B} \delta_f\beta \right)$$

$$p_{nt}^B = \left[ 1 - \frac{A^2}{(2B)^2} \right]^{-1} \times \left( \frac{A^2}{(2B)^2} (\tau(1 - \delta_c) + \delta_ca) - \frac{A \cdot C}{(2B)^2} \delta_f\beta \right. \quad (\text{A.1.58})$$

$$\left. + \frac{A}{2B} (\tau(1 - \delta_c) - \delta_ca - \delta_cb) - \frac{C}{2B} \delta_f\beta \right)$$

Note that the optimal price strategies are independent of  $x_t$ . Applying  $p_{nt}^A - p_{nt}^B = a + bx_t$  we see that  $b = 0$  for all  $\delta_c$ , which also leads to  $a = 0$ :

$$p_{nt}^A - p_{nt}^B = \left[1 - \frac{A^2}{(2B)^2}\right]^{-1} \left( \left(\frac{A}{2B} - 1\right) \frac{A}{2B} (2\delta_c a + \delta_c b) \right) + 0 \cdot x_t \quad (\text{A.1.59})$$

$$= a + bx_t \quad (\text{A.1.60})$$

From  $a = \frac{-2A\delta_c}{2B+A}a$ , we obtain that  $a = 0$ . Therefore, in equilibrium  $p_{nt}^A = p_{nt}^B$ .

Applying  $a = b = 0$ , we can match the expression for the optimal  $p_{nt}^A$  with  $e + fx_t$  and identify  $e$ :

$$p_{nt}^A = [2B - A]^{-1} (A\tau(1 - \delta_c) - C\delta_f\beta) \quad (\text{A.1.61})$$

$$= e + 0 \cdot x_t$$

where now  $A = 2\tau(1 - \delta_c) + 4\delta_f\tau$ ,  $B = 2\tau(1 - \delta_c) + 2\delta_f\tau$  and  $C = 2\tau(1 - \delta_c)$ . Since  $a = b = 0$ , we also have  $p_{nt}^B = e$ .

To find  $e$ , we match the coefficients in the value functions

$$V^A(x_t) = \alpha + \beta x_t + \gamma x_t^2 \quad (\text{A.1.62})$$

$$= (\tau + s + e - 2\tau x_t)x_t + e\frac{1}{2} + \delta_f \left( \alpha + \beta\frac{1}{2} + \gamma \left(\frac{1}{2}\right)^2 \right)$$

from which we obtain  $\beta = \tau + s + e$  and  $\gamma = -2\tau$ . Substituting for  $\beta$  in  $e$ ,

$$e = \frac{(2\tau(1 - \delta_c) + 4\delta_f\tau)\tau(1 - \delta_c) - 2\tau(1 - \delta_c)\delta_f(\tau + s + e)}{2\tau(1 - \delta_c)}$$

$$e = \frac{(1 - \delta_c)\tau - \delta_f(s - \tau)}{1 + \delta_f} \quad (\text{A.1.63})$$

Therefore,  $p_{nt}^A = p_{nt}^B = ((1 - \delta_c)\tau - \delta_f(s - \tau))/(1 + \delta_f)$  and  $\beta = ((2 + \delta_f - \delta_c)\tau + s)/(1 + \delta_f)$ . From the equality of the firms' prices, we obtain that  $x_{t+1} = 1/2$ , which is also the steady-state distribution of the market since it falls within the no-poaching region where firms always set  $p_{nt}^A = p_{nt}^B$ .

Having found the optimal  $p_{nt}$ , it is straightforward to show that indeed  $\hat{q}_{ii} > 1/2$  when  $s > \delta_c\tau$  and  $\hat{q}_{ii} = 1$  when  $s \geq (2 + 2\delta_f + \delta_c)\tau$  since

$$\hat{q}_{ii} = \frac{\tau + s + p_{nt}^i}{4\tau} \quad (\text{A.1.64})$$

$$= \frac{(2(1 + \delta_f) - \delta_c)\tau + s}{4\tau(1 + \delta_f)} \quad (\text{A.1.65})$$

Hence, for  $s > \delta_c\tau$  our conjecture that there is complete customer lock-in for some  $x_t$  close to the middle is correct.

We now find the limits of the no-poaching region,  $(\tilde{x}_m, 1 - \tilde{x}_m)$ , which are determined by the values of  $x_t$  that guarantee that neither firm has a profitable deviation in a strategy that involves poaching. Suppose that firm A starts period  $t$  with a relatively low market share and considers deviating in period  $t$  by selecting a price  $\bar{p}_{nt}^A > 0$  such that  $q_{BA}(\bar{p}_{nt}^A) > 0$ . From the proof of Proposition 1 we know that when firm A intends to poach its best response function is given by (A.1.3).

Applying  $a = b = 0$  and using  $C = 2\tau(1 - \delta_c)$ , we can write the optimal deviating price as

$$\begin{aligned} \bar{p}_{nt}^A(p_{nt}^B) = & [8\tau C + 2C^2 - 8\tau\delta_f\gamma]^{-1} \left( 4\tau(C - 2\delta_f\gamma)(\tau(1 - \delta_c) + p_{nt}^B) \right. \\ & \left. - C^2(4\tau x_t + s - 3\tau) - 4\tau C\delta_f\beta \right) \end{aligned} \quad (\text{A.1.66})$$

The proposed equilibrium price for firm A is given by

$$p_{nt}^A(p_{nt}^B) = [2(C - \delta_f\gamma)]^{-1} \left( (C - \delta_f\gamma)(\tau(1 - \delta_c) + p_{nt}^B) - C\delta_f\beta \right) \quad (\text{A.1.67})$$

and we can express  $\bar{p}_{nt}^A$  in terms of  $p_{nt}^A$ :

$$\bar{p}_{nt}^A = \frac{8\tau C - 8\tau\delta_f\gamma}{8\tau C + 2C^2 - 8\tau\delta_f\gamma} p_{nt}^A + \frac{C^2}{8\tau C + 2C^2 - 8\tau\delta_f\gamma} (3\tau - s - 4\tau x_t) \quad (\text{A.1.68})$$

Note that as  $\delta_c \rightarrow 1$ ,  $C \rightarrow 0$  and, therefore,  $\bar{p}_{nt}^A \rightarrow p_{nt}^A$  - the optimal deviation price converges to the equilibrium price and we have shown that  $q_{BA}(p_{nt}^A) = 0$ . However, when consumers are not very patient, a deviation to a poaching strategy is feasible when  $q_{BA}(\bar{p}_{nt}^A) > 0$ . Defining  $M = 4\tau C - 4\tau\delta_f\gamma$  we can restate this requirement in terms of (A.1.68) and identify the highest level of firm A's market share that would render poaching feasible:

$$x_t < \underline{x} = \frac{3\tau - s}{4\tau} - \frac{2M}{4\tau(2M + C^2)} e \quad (\text{A.1.69})$$

Hence, firm A has room for deviation if  $\tilde{x}_m < \underline{x}$ .

Firm A does not have a profitable deviation in poaching if  $V^A(p_{nt}^A) \geq V^A(\bar{p}_{nt}^A)$ . Again, after some regrouping and using (A.1.66) and (A.1.67), this inequality reduces to

$$(M + C^2)(\bar{p}_{nt}^A)^2 \leq M(p_{nt}^A)^2 \quad (\text{A.1.70})$$

Substituting in the value of  $\bar{p}_{nt}^A$  from (A.1.68), we find that firm A will not deviate to poaching if its market share is sufficiently high:

$$x_t \geq \hat{x}_m = \frac{3\tau - s}{4\tau} - \frac{2(\sqrt{M(M + C^2)} - Me)}{4\tau C^2} \quad (\text{A.1.71})$$

By symmetry, we can conclude that firm B will not deviate to poaching when  $x_t \geq 1 - \hat{x}_m$ .

From (A.1.71) and (A.1.69) we can see that  $\hat{x}_m \leq \underline{x}$  for all  $p_{nt}^A \geq 0$ , which guarantees that indeed there is room for deviation within the no-poaching region although it is not optimal to do so. Note that poaching is not feasible under  $p_{nt}^A < 0$  because the deviation price must be at least zero, which implies that  $\bar{p}_{nt}^A > p_{nt}^A$  and since  $q_{BA}$  is decreasing in  $p_{nt}^A$ ,  $q_{BA}(\bar{p}_{nt}^A) = 0$ . Therefore, it is reasonable to consider deviations to poaching only when  $p_{nt}^A \geq 0$ .

Note that if  $\hat{x}_m \leq 1 - \hat{q}_{BB}$ , firm A will have no profitable deviations within the no-poaching region. On the other hand if  $\hat{x}_m > 1 - \hat{q}_{BB}$ , then  $(\hat{x}_m, 1 - \hat{x}_m)$  will define the boundaries of the no-poaching region. For this reason, we state that  $\tilde{x}_m = \max(0, 1 - \hat{q}_{BB}, \hat{x}_m)$ .

Finally, we check that the second-order conditions are satisfied for the coefficients found above:

$$\begin{aligned}
& - \frac{2(2\tau - 2\tau\delta_c - \delta_cb - \delta_f\gamma)}{2\tau - 2\tau\delta_c - \delta_cb} < 0 & \text{(A.1.72)} \\
& - \frac{2(2\tau - 2\tau\delta_c - \delta_f(-2\tau))}{2\tau - 2\tau\delta_c} < 0 \\
& \frac{2(1 - \delta_c + \delta_f)}{1 - \delta_c} < 0 \quad \forall \delta_f > 0, \delta_c > 0
\end{aligned}$$

□

### A.1.5 Proof of Proposition 3

*Proof.* Using (2.3.51) and (2.3.52) we derive the best response functions for each firm:

$$\begin{aligned}
p_{nt}^A(p_{nt}^B) &= \frac{2\tau - 2\tau\delta_c - \delta_cb - 2\delta_f\gamma}{2(2\tau - 2\tau\delta_c - \delta_cb - \delta_f\gamma)} (\tau(1 - \delta_c) + \delta_ca + p_{nt}^B) & \text{(A.1.73)} \\
& - \frac{2\tau - 2\tau\delta_c - \delta_cb}{2(2\tau - 2\tau\delta_c - \delta_cb - \delta_f\gamma)} \delta_f\beta
\end{aligned}$$

$$\begin{aligned}
p_{nt}^B(p_{nt}^A) &= (8\tau(2\tau - 2\tau\delta_c - \delta_cb) + 2(2\tau - 2\tau\delta_c - \delta_cb)^2 - 8\tau\delta_f\gamma)^{-1} & \text{(A.1.74)} \\
& \times \left[ (4\tau(2\tau - 2\tau\delta_c - \delta_cb) - 8\tau\delta_f\gamma) (\tau(1 - \delta_c) - \delta_ca - \delta_cb + p_{nt}^A) \right. \\
& \quad + (2\tau - 2\tau\delta_c - \delta_cb)^2(4\tau x_t - \tau - s) \\
& \quad \left. - 4\tau(2\tau - 2\tau\delta_c - \delta_cb)\delta_f\beta \right]
\end{aligned}$$

Note that because we assume that  $x_{t+1} \in (\tilde{x}_m, 1 - \tilde{x}_m)$ , next period prices are formed according to the affine functions that we specified for the no-poaching region.



Therefore, we can apply  $a = b = 0$ ,  $\beta = ((2 + \delta_f - \delta_c)\tau + s)/(1 + \delta_f)$ ,  $\gamma = -2\tau$ , in which case the best response functions above fully determine the optimal values of  $p_{nt}^A$  and  $p_{nt}^B$ . In particular,

$$p_{nt}^A = \frac{(7 - 2\delta_c^3 + 13\delta_f + 6\delta_f^2 + \delta_c^2(11 + \delta_f) + 2\delta_c(-8 - 7\delta_f + \delta_f^2))\tau}{2(1 + \delta_f)(5 + 2\delta_c^2 + 6\delta_f - \delta_c(7 + 2\delta_f))} \quad (\text{A.1.75})$$

$$- \frac{(1 + 11\delta_f + 10\delta_f^2 + \delta_c^2(1 + 3\delta_f) - 2\delta_c(1 + 7\delta_f + \delta_f^2))s}{2(1 + \delta_f)(5 + 2\delta_c^2 + 6\delta_f - \delta_c(7 + 2\delta_f))}$$

$$+ \frac{2(1 - \delta_c)(1 - \delta_c + 2\delta_f)\tau}{5 + 2\delta_c^2 + 6\delta_f - \delta_c(7 + 2\delta_f)}x_t$$

$$p_{nt}^B = \frac{(\delta_c(4 + 4\delta_f - \delta_f^2) - 2 - \delta_c^2(2 - \delta_f) - 5\delta_f - 3\delta_f^2)\tau}{(1 + \delta_f)(5 + 2\delta_c^2 + 6\delta_f - \delta_c(7 + 2\delta_f))} \quad (\text{A.1.76})$$

$$+ \frac{(1 + 5\delta_f + 5\delta_f^2 + \delta_c^2(2 + 6\delta_f + \delta_f^2))s}{(1 + \delta_f)(5 + 2\delta_c^2 + 6\delta_f - \delta_c(7 + 2\delta_f))}$$

$$+ \frac{4(1 - \delta_c)(1 - \delta_c + 2\delta_f)\tau}{5 + 2\delta_c^2 + 6\delta_f - \delta_c(7 + 2\delta_f)}x_t$$

We now find the range of  $x_t$  such that, conditional on  $p_{nt}^A$  as described in (A.1.76), firm B does not have a profitable deviation in choosing an introductory price such that it does not attract any switchers. Let  $\bar{p}_{nt}^B$  stand for the optimal deviation price, which is given by:

$$\bar{p}_{nt}^B = \frac{2\tau - 2\tau\delta_c - \delta_cb - 2\delta_f\gamma}{2(2\tau - 2\tau\delta_c - \delta_cb - \delta_f\gamma)} (\tau(1 - \delta_c) - \delta_ca - \delta_cb + p_{nt}^A) \quad (\text{A.1.77})$$

$$- \frac{2\tau - 2\tau\delta_c - \delta_cb}{2(2\tau - 2\tau\delta_c - \delta_cb - \delta_f\gamma)}\delta_f\beta$$

Checking that  $V^B(p_{nt}^B) \geq V^B(\bar{p}_{nt}^B)$  reduces to

$$(M + C^2)(p_{nt}^B)^2 \geq M(\bar{p}_{nt}^B)^2 \quad (\text{A.1.78})$$

which implies that firm B will not deviate to a no-poaching strategy if

$$x_t \geq 1 - \tilde{x}_s = \frac{\tau + s}{4\tau} + \frac{\sqrt{M(M + C^2)} - M}{4\tau C^2 \sqrt{M(M + C^2)}} p_{nt}^B \quad (\text{A.1.79})$$

Note that if  $1 - \tilde{x}_s < 1 - \tilde{x}_m$ , then the region, in which B poaches in equilibrium while A does not is defined by  $(1 - \tilde{x}_m, 1)$ . On the other hand, if  $1 - \tilde{x}_s > 1 - \tilde{x}_m$ , there are no pure-strategy equilibria in  $(1 - \tilde{x}_s, 1 - \tilde{x}_m)$  – if the firms follow the strategies prescribed in (A.1.76) and (A.1.77), B has a profitable deviation in selecting a price such that it does not poach. If B does not poach, then A’s best response is described by Proposition 2. However, as soon as A chooses to follow this price strategy, B has a profitable deviation in poaching.

By similar arguments we can identify an equilibrium in the case  $x_t \in (0, \tilde{x}_m)$ , where firm A has a profitable deviation in poaching.

□

# Appendix B

## Appendix to Chapter 3

### B.1 Proofs

#### B.1.1 Proof of Proposition 1.

*Proof.* The set-up of the problem is identical to the one discussed in Section 2.3.1 of Chapter 2. Recall that the firms' optimal price strategies are expected to depend on the state variable,  $x_t$ , and we defined the firms' price strategies and value functions as affine and quadratic functions in  $x_t$ , respectively. In the Proof of Proposition 1 in Appendix A, where we have shown that the undetermined coefficients characterizing these functions,  $a$ ,  $e$ ,  $f$ ,  $\beta$  and  $\gamma$  converge to zero as  $\delta_c \rightarrow 1$  and the firms' optimal price strategies become independent of the market share. In the limit,  $\delta_c = 1$ , we have that  $a = b = 0$ , which immediately implies that  $p_{nt}^A = p_{nt}^B$  regardless of the current distribution of the market. From  $e = f = 0$ , we also see that  $p_{nt}^A = p_{nt}^B = 0$ , or marginal cost if  $c > 0$ . Throughout the rest of the proof I assume that marginal

cost is positive so that  $p_n^A = p_n^B = c$ .

At this point we assume that in case of a tie the market is evenly split. Since prices are independent of market share, the equilibrium where  $p_n^A = p_n^B = c$  and  $x_t = 1/2$  is a steady state. In addition, from the Proof of Proposition 1 in Appendix A we have that in steady state:

$$p_{ot}^i(p_{nt}^j = c) = (c + \tau + s + c)/2 = c + \frac{\tau + s}{2} \quad (\text{B.1.1})$$

$$\hat{q}_{ii}(p_{nt}^j = c) = (\tau + s + c - c)/(4\tau) = \frac{\tau + s}{4\tau} \quad (\text{B.1.2})$$

$$q_{AB}(p_{nt}^B = c) = 1/2 - \frac{\tau + s}{4\tau} = \frac{\tau - s}{4\tau} \quad (\text{B.1.3})$$

$$q_{BA}(p_{nt}^A = c) = 1/2 - \frac{\tau + s}{4\tau} = \frac{\tau - s}{4\tau} \quad (\text{B.1.4})$$

$$(\text{B.1.5})$$

To show that neither firm has a profitable deviation from the proposed equilibrium price,  $p_{nt} = c$ , we need the two lemmas stated in the text to describe market dynamics when  $\delta_c = 1$ .

- Lemma 1: Competition for newcomers intensifies as consumers become more patient. As a result,  $p_n^i$  and  $p_o^i$  fall as  $\delta_c$  goes up.

*Proof.* Using the equilibrium result  $a = -b/2$  (see (A.1.9)) we can rewrite  $x_{t+1}$

as follows:

$$\begin{aligned}
x_{t+1} &= \frac{\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - p_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b} \\
&= \frac{1}{2} + \frac{p_{nt}^B - p_{nt}^A}{2\tau - 2\tau\delta_c - \delta_c b}
\end{aligned} \tag{B.1.6}$$

Let  $w = 1/(2\tau - 2\tau\delta_c - \delta_c b)$  indicate the weight of the price differential on the location of the marginal consumers,  $x_{t+1}$ . On the equilibrium path  $b \leq 0$  and  $\partial b/\partial\delta_c < 0$ , so  $\partial w/\partial\delta_c > 0$  - as consumer patience increases, the marginal newcomer becomes more sensitive to the difference between the introductory prices offered today. As a result,  $p_n$  goes down. Since  $p_o$  is increasing in the rival's  $p_n$ , as introductory prices fall, regular prices fall as well.  $\square$

- Lemma 2: When  $\delta_c = 1$ , demand from newcomers is perfectly elastic.

*Proof.* First note that for  $\delta_c = 1$ , we have  $p_{nt}^A = p_{nt+1}^A = p_{nt+1}^B$ . Designate this equilibrium price as  $p$  and consider a deviation price  $p_{nt}^A$  for firm A. The marginal newcomer will either switch next period or will stay with the current supplier. In both cases her consumption expenditure in the second period will be at least as high as the expenditure from switching. For example, if she purchases from firm A in her first period she will switch if  $p + \tau(1 - x) + s < p + \tau x$ . If the consumer stays, she will be the marginal stayer and will be offered a price such that she is just indifferent between switching and staying:  $p + \tau(1 - x) + s = p + \tau x$ . In either case, in her second period the marginal consumer will spend at least  $p + \tau(1 - x) + s$  if she first purchases from A

and  $p + \tau x + s$  if she purchases from B. Hence, a newcomer located at  $x$  will purchase from A if:

$$p_{nt}^A + \tau x + (p + \tau(1 - x) + s) \leq p + \tau x + (p + \tau x + s)$$

$$p_{nt}^A \leq p$$

It is clear that for  $p_{nt}^A > p$ , the inequality above cannot be satisfied for any  $x$ . Therefore, if A deviates to a price above the proposed equilibrium price,  $p$ , it will make no sales to newcomers. Similarly, if firm A offers a price below  $p$  it will capture the entire market of newcomers. Hence, newcomers' demand becomes perfectly elastic when consumers are infinitely patient.  $\square$

### *Exit Costs*

Lemma 2 shows that if one firm deviates by raising its price above marginal cost, it forgoes sales to newcomers and starts next period with no market share. The only incentive for a firm to raise its price is to maximize profits from switchers. Profits from switchers would be greatest when the firm starts the period with no market share because of the higher mass of potential switchers.

Suppose that in period  $\hat{t}$  firm A starts with  $x_{\hat{t}} = 0$  and deviates from the proposed equilibrium by setting  $p_{n\hat{t}}^A > p_{n\hat{t}}^B$  while  $p_{n\hat{t}}^B \rightarrow 0$ . From Lemma 2 we see that at this price  $q_{1A} = 0$ , so  $x_{\hat{t}+1} = 0$ . Therefore, firm A will set  $p_{n\hat{t}}^A$  so as to

maximize profits from switchers in period  $\hat{t}$ :

$$p_{n\hat{t}}^A = \arg \max p_{n\hat{t}}^A \cdot \frac{3\tau - s - p_{n\hat{t}}^A}{4\tau} \quad (\text{B.1.7})$$

$$= \frac{3\tau - s}{2} \quad (\text{B.1.8})$$

At this price, sales to switchers equal  $q_{BA,\hat{t}} = (3\tau - s)/(8\tau)$  and the maximum profit from poaching in period  $\hat{t}$  equals

$$\hat{\Pi}_{\hat{t}}^A = \frac{(3\tau - s)^2}{16\tau} \quad (\text{B.1.9})$$

The net present value of firm A's deviation is

$$\frac{(3\tau - s)^2}{16\tau} - E + \sum_{\sigma=2}^{\infty} \delta_f^\sigma \bar{\Pi} \quad (\text{B.1.10})$$

where  $E$  stands for exit costs (to be incurred at the end of the period in which the firm makes no sales to newcomers) and  $\bar{\Pi}$  indicates the per-period level of profits within the poaching region, which is equal to  $(\tau + s)^2/(8\tau)$ . Comparing the payoff from a one-time deviation to the payoff from staying on the equilibrium path we can obtain the minimum level of exit costs that guarantees that firm A has no profitable deviation in not selling to newcomers:

$$\frac{(3\tau - s)^2}{16\tau} - E + \sum_{\sigma=2}^{\infty} \delta_f^\sigma \bar{\Pi} \leq \sum_{\sigma=1}^{\infty} \delta_f^\sigma \bar{\Pi} \quad (\text{B.1.11})$$

$$E \geq \underline{E} = \frac{(3\tau - s)^2}{16\tau} - \delta_f \frac{(\tau + s)^2}{8\tau} \quad (\text{B.1.12})$$

As long as  $E \geq \underline{E}$  firm A does not have a profitable deviation in raising its price above marginal cost. The same argument goes for firm B.

Next, consider a deviation such that firm A undercuts the rival by setting a price just below marginal cost. Note from (B.1.2) that at  $p_n = c$ , the optimal mass of loyal customers for each firm,  $\hat{q}_{ii}(p_{nt}^j = c) = \frac{\tau+s}{4\tau}$ , does not exceed one half since we specified that  $s \leq \tau$ . Therefore, capturing the full market of newcomers in the preceding period brings no additional gains since neither firm keeps more than half of the market. In addition, sales to switchers are profit-neutral as well (price equals marginal cost), implying that neither firm can derive additional gains from undercutting the rival. Hence, the firms do not have a profitable deviation in lowering  $p_n$  below cost.

From the arguments above it also becomes clear that any sharing rule can ensure a pure strategy equilibrium at marginal cost as long as the firms capture their respective segments of loyal customers.  $\square$

### B.1.2 Proof of Corollary 1

*Proof.* From  $a = b/2$  and  $x_{t+1} = (\tau(1 - \delta_c) + \delta_c a + p_{nt}^B - p_{nt}^A)/(2\tau - 2\tau\delta_c - \delta_c b)$  we can see that convergence to steady state occurs according to

$$x_{t+1} - \frac{1}{2} = \frac{-b}{2\tau - 2\tau\delta_c - \delta_c b} \left( x_t - \frac{1}{2} \right) \quad (\text{B.1.13})$$

Since  $-b/(2\tau - 2\tau\delta_c - \delta_c b) = y^{-1}$  and  $y \in (-3/2, -1)$ , convergence is monotonic and becomes infinitely slow when  $\delta_f \rightarrow 1$ .



For  $\delta_c = 1$ ,  $b = f = 0$ , which implies that firms' introductory prices are independent of market share and equal to each other ( $a = b = 0$ ) – hence, convergence to  $x_{t+1} = 1/2$  occurs in just one period starting from any initial distribution of the market,  $x_t$ . □

### B.1.3 Proof of Lemma 3.

*Proof.* (a) From Lemma 2 we see that the demand from newcomers is perfectly elastic. Therefore, firm  $i$  can capture the entire market of newcomers by undercutting, i.e. setting  $p_{nt}^{i*} = p_{nt}^j - \epsilon$  where  $\epsilon \rightarrow 0$ . When  $p_{nt}^j > c^i$  the payoff from undercutting is strictly higher than the payoff from matching the rival's price because sales to newcomers double, the profit margin on newcomers is positive and the corresponding loss of revenue from sales to switchers is negligible as  $\epsilon \rightarrow 0$ . The payoff from matching the rival's price is also higher than the payoff from exceeding it because the latter strategy results in sales to switchers only and the presence of exit costs as outlined in Proposition 1 ensures that this strategy is strictly dominated. Finally, note that firm  $i$  may also choose to undercut by more than  $\epsilon$  if  $p_{nt}^j$  exceeds the price that maximizes  $i$ 's joint profits from newcomers and switchers.

(b) First note that when  $p_{nt}^j \leq c^i$  undercutting is costly for firm  $i$  and capturing market share beyond firm  $i$ 's loyal customer segment has no future value. Therefore, undercutting will yield a strictly lower payoff than matching the rival's price.

Furthermore, when  $p_{nt}^j$  is sufficiently low, the payoff from investing in market

share falls below the payoff from targeting switchers only at a price above cost.

Therefore, firm  $i$  will raise its price above the rival's when  $p_{nt}^j$  is sufficiently low.

□

#### B.1.4 Proof of Lemma 4.

*Proof.* We define  $\underline{p}^i$  as the break-even price that yields firm  $i$  indifferent between competing in the newcomers market, in which case it sells to both newcomers and switchers, and targeting switchers only. The decision not to sell to newcomers takes into account the forgone profits from loyal customers next period, the exit costs to be incurred at the end of the current period and the possibly lower per-generation profits next period due to starting with no market share. If the market price falls below  $\underline{p}^i$ , firm  $i$  is better off targeting switchers only because the investment in market share would exceed the returns. Thus,  $\underline{p}^i$  represents the minimum price at which firm  $i$  would be willing to sell to newcomers.

(a) By the definition of  $\underline{p}^i$ , when  $\underline{p}^i \leq p_{nt}^j$  firm  $i$  will compete for market share. Thus, it will either match or undercut the rival's price. By Lemma 3 undercutting is a dominated strategy when  $p_{nt}^j \leq c^i$  so firm  $i$ 's maximizes its payoff by setting  $p_{nt}^{i*} = p_{nt}^j$ .

(b) Similarly, when  $\underline{p}^i > p_{nt}^j$  firm  $i$  realizes a higher payoff if it targets switchers only, which entails setting  $p_{nt}^i > c^i$  (for sales to switchers to be profitable). Together with  $c^i \geq p_{nt}^j$ , we obtain that  $p_{nt}^{i*} > p_{nt}^j$ . Note that even if  $c^i$  is high enough to raise  $\underline{p}^i$  such as to suppress demand from switchers ( $q_{ji} = 0$  when

$p_{nt}^i \geq c^j + \tau - s$ ), firm  $i$  is still strictly better off setting  $p_{nt}^i > p_{nt}^j$ , in which case it makes no sales to new customers.

□

### B.1.5 Proof of Proposition 2

*Proof.* (a) To show that  $p_{nt}^A = p_{nt}^B = p_n^*$ , we will first derive conditions, under which firm  $A$  does not have a profitable deviation from the proposed equilibrium. Let  $p_{nt}^B = p_n^*$ . Since  $p_n^* = c$ , which is less than  $\tilde{c}$ , firm  $A$  has no profitable deviation in undercutting firm  $B$ 's price as established in part (b) of Lemma 3. The only possible profitable deviation for firm  $A$  would be to raise its price above cost, which would imply that it makes no sales to newcomers (Lemma 2). Therefore, it will set  $p_{nt}^A$  with the objective of maximizing profits from switchers in the current period. Note that at this point the minimum level of exit costs,  $\underline{E}$  is not sufficient to deter  $A$  from targeting switchers only because the payoff from investing in market share is lower than the one used in (B.1.11) to derive  $\underline{E}$ . Under cost asymmetry, firm  $A$ 's demand from switchers is given by  $q_{BA}(p_{nt}^A) = (\tau - s - p_{nt}^A + c)/(4\tau)$ . Since  $x_t = 1/2$ , firm  $A$  cannot induce all of firm  $B$ 's previous customers to switch unless it lowers its price below  $c - s$ , which is clearly not profitable. Therefore, the price that would maximize profits

from switchers, is given by

$$\max (p_{nt}^A - \tilde{c}) \cdot \frac{\tau - s - p_{nt}^A + c}{4\tau} \quad (\text{B.1.14})$$

$$p_{nt}^A = \frac{\tau - s + c + \tilde{c}}{2} \quad (\text{B.1.15})$$

from which it can be seen that firm A's optimal price that targets switchers only is greater than the rival's current price,  $p_n^*$ .

If firm  $A$  sets  $p_{nt}^A = p_n^*$ , it will capture half of the newcomers market because  $p_{nt}^A = p_{nt}^B$ , but it will also sell at a price below cost to both newcomers and switchers. However, if  $\Delta c$  is not too high, firm  $A$  will recuperate some of these losses next period when it sells to the loyal customers attracted today. On the other hand, if firm  $A$  sets  $p_{nt}^A > p_{nt}^B$ , it will make no sales to newcomers, will forgo profits from loyal customers next period and will incur exit costs at the end of period  $t$ . Since the loss per unit sold to new customers and the maximum profit from targeting switchers only depend on  $\Delta c$ , we can find the highest cost differential, within which firm A's stream of profits from matching  $B$ 's price and investing in market share is higher than its stream of profits if selling to switchers only. Since we assume the shock lasts one period only and this is common knowledge, both firms know that they will start next period with equal marginal cost. Therefore,  $p_{nt+1}^A = p_{nt+1}^B = c$  and firm  $A$ 's profit from investing in market share today equals its steady-state level of profit:  $\bar{\Pi} = (\tau + s)^2 / (8\tau)$ . In period  $t + 1$  the market goes back to equilibrium so we only need to analyze firm  $A$ 's discounted payoff over periods  $t$  and  $t + 1$ . Firm  $A$ 's payoff from setting

$p_{nt}^A = p_{nt}^B$  when  $p_{nt}^B = c$  weakly dominates the payoff from targeting switchers.

$$\Pi(p_{nt}^A = p_{nt}^B) \geq \Pi(p_{nt}^A > p_{nt}^B) \quad (\text{B.1.16})$$

$$\begin{aligned} (c - \tilde{c})(q_{1A} + q_{BA}) + \delta_f \frac{(\tau + s)^2}{8\tau} + \sum_{\sigma=t+1}^{\infty} \delta_f^\sigma \bar{\Pi} \\ \geq -E + \left( \frac{\tau - s + c + \tilde{c}}{2} - \tilde{c} \right) \cdot \max \left( \frac{\tau - s + c - \tilde{c}}{8\tau}, \frac{1}{2} \right) + \delta_f \cdot 0 + \sum_{\sigma=t+1}^{\infty} \delta_f^\sigma \bar{\Pi} \end{aligned} \quad (\text{B.1.17})$$

where  $(\tau - s + c - \tilde{c})/(8\tau)$  is the profit-maximizing level of sales to switchers.

At  $p_{nt}^A = p_{nt}^B = c$  firm  $A$ 's sales to switchers are given by  $q_{BA} = (\tau - s)/(4\tau)$  as stated in Proposition 1. At  $p_{nt}^A = (\tau - s + c + \tilde{c})/2$ , demand from switchers is positive as long as  $\tilde{c} - c < \tau - s$ . Therefore, if  $\tilde{c} - c < \tau - s$ , equation (B.1.16) becomes

$$\begin{aligned} (c - \tilde{c}) \left( \frac{1}{2} + \frac{\tau - s}{4\tau} \right) + \delta_f \frac{(\tau + s)^2}{8\tau} \\ \geq -E + \left( \frac{\tau - s + c - \tilde{c}}{2} \right) \cdot \left( \frac{\tau - s + c - \tilde{c}}{8\tau} \right) \end{aligned} \quad (\text{B.1.18})$$

and can be rewritten as

$$(\tilde{c} - c)^2 + 2(5\tau - s)(\tilde{c} - c) - 2\delta_f(\tau + s)^2 - 16\tau E + (\tau - s)^2 \leq 0 \quad (\text{B.1.19})$$

Using  $\Delta c = \tilde{c} - c$ , the positive root of (B.1.19) is given by

$$\overline{\Delta c}_1 = \sqrt{(5\tau - s)^2 + 2\delta_f(\tau + s)^2 + 16\tau E - (\tau - s)^2} - (5\tau - s) \quad (\text{B.1.20})$$

and the inequality from (B.1.18) is satisfied for  $\Delta c \in [0, \overline{\Delta c}_1]$ . Therefore, for  $\Delta c \leq \overline{\Delta c}_1$ , the payoff from maintaining  $p_{nt}^A = p_{nt}^B = c$  weakly dominates the payoff from targeting switchers only by setting  $p_{nt}^A > p_{nt}^B$ .

Alternatively, if  $\tilde{c} - c \geq \tau - s$ , then the condition in B.1.16 becomes

$$(c - \tilde{c}) \left( \frac{1}{2} + \frac{\tau - s}{4\tau} \right) + \delta_f \left( \frac{(\tau + s)^2}{8\tau} \right) \geq -E \quad (\text{B.1.21})$$

and is satisfied for

$$\Delta c \leq \overline{\Delta c}_2 = \frac{4\tau}{3\tau - s} \left( E + \frac{\delta_f(\tau + s)^2}{8\tau} \right) \quad (\text{B.1.22})$$

Therefore, we have established that for  $\Delta c \leq \overline{\Delta c}$  where  $\overline{\Delta c} = \overline{\Delta c}_1$  if  $\Delta c < \tau - s$  and  $\overline{\Delta c} = \overline{\Delta c}_2$  if  $\Delta c \geq \tau - s$ , firm  $A$  does not have an incentive to deviate to a higher introductory price despite its higher marginal cost. Proposition 1 has established that firm  $B$  does not have a profitable deviation when  $p_{nt}^A = c$ , either, so  $p_{nt}^A = p_{nt}^B = c$  is indeed an equilibrium in pure strategies.

The rest of the statements in part (a) follow immediately since  $p_{nt}^A = p_{nt}^B = p_n^* = c$ . I only note that firm  $A$ 's price to loyal customers adjusts upwards to reflect the firm's higher marginal cost; as a result, its loyal customers segment

in period  $t$  shrinks ( $q_{AA,t}(p_{nt}^B) < q_{AA}^*$ ). From B.1.1, we obtain

$$\begin{aligned} p_{ot}^A(p_{nt}^B) &= \frac{\tilde{c} + \tau + s + p_{nt}^B}{2} \\ &= \frac{\tilde{c} + \tau + s + c}{2} \end{aligned} \tag{B.1.23}$$

$$> p_o^*$$

$$\begin{aligned} q_{AA,t}(p_{nt}^B) &= \frac{\tau + s + p_{nt}^B - \tilde{c}}{4\tau} \\ &= \frac{\tau + s + c - \tilde{c}}{4\tau} \end{aligned} \tag{B.1.24}$$

$$< q_{AA}^*$$

*Note on non-uniqueness:*

Finally, I note that the pure-strategy equilibrium described in Proposition 2 is not unique. Any pair of prices such that  $p_{nt}^A = p_{nt}^B = p$  and  $p \in [\underline{p}^A, c]$  would constitute a Nash equilibrium in period  $t$  and a subgame perfect equilibrium of the subgame from period  $t$  onwards. Whenever  $p_{nt}^A$  is below cost, by Lemma 4 firm B's best response is to match A's price as long as the cost of acquiring market share by selling below marginal cost does not exceed the future profits that can be derived from it. Similarly, if  $p_{nt}^B$  is below cost, firm A's best response is to match B's price until the profits from market share are exhausted. Since A's profits from future market share are smaller and its break-even price higher,  $\underline{p}^A$  determines the lowest price level, at which a tie would constitute a Nash equilibrium.

(b) To prove this part of the proposition I will use the concept of a break-even price

as defined in Lemma 4 to show that firm  $A$  does not have profitable deviations away from the proposed equilibrium (part (i) below).

Part (a) of Lemma 4 states that firm  $A$  will match firm  $B$ 's price as long as  $p_{nt}^B$  is at or above firm  $A$ 's break-even price,  $\underline{p}^A$ . Note that we can use the proof in part (a) of this proposition to derive  $\underline{p}^A$ . We can express  $\underline{p}^A$  in terms of the maximum loss per unit sold to a new customer that firm  $A$  is willing to incur in order to capture market share. We derived  $\overline{\Delta c}$  as the maximum difference between firm  $A$ 's cost and the rival's offer,  $p_{nt}^B = c$ , such that firm  $A$  competes for newcomers. Therefore, firm  $A$ 's break-even price can be stated in terms of the maximum difference between firm  $A$ 's cost and the rival's offer,  $p_{nt}^B = c$ , such that firm  $A$  competes for newcomers. Therefore, firm  $A$ 's break-even price can be stated as:

$$\underline{p}^A = \tilde{c} - \overline{\Delta c} \tag{B.1.25}$$

From part (b) of Lemma 4 we know that if  $p_{nt}^B$  is below  $\underline{p}^A$ , firm  $A$  will not lower its price any further and will forgo profits from market share. In particular, firm  $A$ 's best response is to set a price that maximize profits from switchers. Indicate this price by  $\hat{p}^A > \tilde{c}$  and suppose that firm  $A$  deviates from the steady-state equilibrium  $p_{nt}^A = p_{nt}^B = c$  by raising its price to  $\hat{p}^A$ . Then, firm  $B$  has an incentive to raise its price to some level above its own marginal cost but below  $\hat{p}^A$ , because it can still capture the entire market of newcomers and can sell to new customers at a price above cost. Let firm  $B$ 's best response to  $p_{nt}^A = \hat{p}^A$  be



given by  $p_{nt}^{B*}(\hat{p}^A) = \hat{p}^A - \eta$ , where  $\eta \in (0, \hat{p}^A - c)$ .

If  $p_{nt}^{B*}(\hat{p}^A) > \tilde{c}$ , by part (a) of Lemma 3 firm  $A$  has an incentive to undercut  $B$ 's price. If  $p_{nt}^{B*}(\hat{p}^A) \leq \tilde{c}$  by part (a) of 4 firm  $A$  would match  $B$ 's price. Similarly, since  $A$ 's price is above  $B$ 's marginal cost,  $B$  has an incentive to undercut as well, and as a result the introductory price drops to  $\underline{p}^A$ . At this point, firm  $A$  sets  $\underline{p}^A$  and does not have an incentive to undercut  $B$ 's price, while  $B$  settles at  $p_{nt}^B < \underline{p}^A$  and captures the entire market of newcomers. However, at  $p_{nt}^B < \underline{p}^A$ , firm  $A$  may have an incentive to raise its price to  $\hat{p}^A$  again, which triggers another round of undercutting. Therefore, without imposing additional conditions on  $\underline{p}^A$ , there will be no equilibrium in pure strategies when  $\tilde{c} - c > \overline{\Delta c}$ .

Suppose that  $(p_{nt}^A, p_{nt}^B) = (\underline{p}^A, \underline{p}^A - \eta)$  and let  $\tilde{c} > \tau - s + c$ . Therefore,  $q_{BA}(p_{nt}^A = \tilde{c}) = 0$  – firm  $A$  cannot sell to switchers at a profit and therefore targeting switchers with any price above  $\tilde{c}$  is not a profitable deviation. Note, however, that  $q_{BA}(\underline{p}^A)$  may still be positive, so firm  $A$  would be selling to switchers at a price below cost if it maintains  $p_{nt}^A = \underline{p}^A$ . Therefore, it would have a profitable deviation in raising its price to at least  $\tilde{c}$  to avoid costly sales to switchers. Then, firm  $B$  would also raise its price to just below  $A$ 's price and a round of undercutting will follow again. However, firm  $A$  will have no profitable deviation if  $q_{BA}(\underline{p}^A) = 0$ , which is true for

$$\underline{p}^A \geq \tau - s + c \tag{B.1.26}$$

Using (B.1.25), we can rewrite the above condition as

$$\tilde{c} - \overline{\Delta c} \geq \underline{\Delta c} = \tau - s + c \quad (\text{B.1.27})$$

which produces

$$\tilde{c} - c \geq \overline{\Delta c} + \tau - s \quad (\text{B.1.28})$$

Therefore, we have derived a sufficient condition to ensure that at  $(p_{nt}^A, p_{nt}^B) = (\underline{p}^A, \underline{p}^A - \eta)$ , firm  $A$  has no profitable deviation.

So far we have shown that when  $\Delta c > \underline{\Delta c}$ , firm  $A$ 's best response to a price at or below  $\underline{p}^A$  is to set  $\underline{p}^A$  itself. On the other hand, firm  $B$ 's best response to  $p_{nt}^A = \underline{p}^A$  is given by  $\min(\hat{p}^B, \underline{p}^A - \epsilon)$ , where  $\hat{p}^B$  is the price that would optimize firm  $B$ 's profits from new customers, conditional on being below  $A$ 's price.<sup>1</sup> Hence, for  $\Delta c > \underline{\Delta c}$  there is an equilibrium in pure strategies, given by  $(p_{nt}^A, p_{nt}^B) = (\underline{p}^A, \min(\hat{p}^B, \underline{p}^A - \epsilon))$ , where  $\epsilon \rightarrow 0$ .

*Profits:*

The result that  $\Pi_{B,t} > \Pi^*$  follows immediately by noting that  $\underline{p}^A > p_n^*$ ,  $p_{ot}^B > p_o^*$ ,  $q_{BB,t} > \hat{q}_{BB}^*$  and  $q_{1B} = 1$ : firm  $B$  realizes higher profits on both loyal and new customers. Specifically,  $B$ 's profit from loyal customers is given by  $(\tau + s + \underline{p}^A - c)^2 / (8\tau)$  for  $\epsilon \rightarrow 0$ , which is greater than its steady-state profit of

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<sup>1</sup>  $\hat{p}_{nt+1}^B = \arg \max(\hat{p}_{nt}^B - c) \cdot \frac{1+x_{t+1}-3\tau-s-\hat{p}_{nt}^B}{4\tau}$  s.t.  $\hat{p}_{nt}^B < \underline{p}^A$

$(\tau + s)^2/(8\tau)$  since  $\underline{p}^A > c$ . Next period, the market goes back to steady state so  $p_{nt}^A = p_{nt}^B = c$ , implying that  $\Pi_{B,t+1} = \Pi^*$

Firm A's profit from loyal customers in period  $t$  is given by  $\Pi_{A,t} = (\tau + s + \underline{p}^A - \tilde{c})^2/(8\tau)$  for  $\epsilon \rightarrow 0$ , which is less than its steady-state profit from loyal customers since  $\underline{p}^A < \tilde{c}$ . Also,  $\Pi_{A,t+1} < \Pi^*$  follows from the fact that in period  $t$  firm A makes no sales to newcomers and does not have loyal customers in period  $t + 1$ , hence  $\Pi_{A,t+1} = 0$ .

□

### B.1.6 Proof of Proposition 3

*Proof.* (a) When  $\Delta c \leq \overline{\Delta c}$  we see from Proposition 2 that  $p_{n,2}^A = p_{n,2}^B = c$  where  $(p_{n,2}^A, p_{n,2}^B)$  are the two firms' prices to new customers in period 2. Firm B's optimal market share in period 2 is unchanged,  $\hat{q}_{BB,2} = q_{BB}^*$ , so any distribution of the market at time 1 that allows firm B to capture newcomers in the range  $(\hat{q}_{BB,2}, 1)$ , i.e. its future loyal customers, will bring in the same profit in period 2. Let  $(p_{n,1}^A, p_{n,1}^B)$  indicate the two firms' introductory prices in period 1. Suppose that  $p_{n,1}^A = p_{n,1}^B = c$  and the market sharing rule is such that B captures all newcomers in  $(1 - q_{BB,2})$ . Firm B does not have a profitable deviation away from  $p_{n,1}^B = c$  because undercutting is costly without bringing in additional revenues, and setting a higher price forgoes next-period profits altogether.

Now consider firm A's motivation to deviate from  $p_{n,1}^A = p_{n,1}^B$  when  $p_{n,1}^B = c$ . For the same reasons as firm B, firm A does not have a strictly profitable deviation

in raising its price. Also, firm A does not have a profitable deviation in lowering its price if it can capture all newcomers in the range  $(0, 1 - q_{BB,2})$ . Under a price tie, a market sharing rule that allows firm A to sell to newcomers located within  $(0, 1 - \hat{q}_{BB,1})$  is crucial to finding a pure-strategy equilibrium because it ensures that firm A will face no demand from switchers in period 2 when it sells below cost. If, instead, the current price strategy led to a distribution of the market such that  $x_2 < \hat{q}_{BB,2}$ , then firm A would have a profitable deviation in undercutting in order to capture the full market and avoid costly sales to switchers next period. Hence, under a market sharing rule that splits the market at  $x_2 = \hat{q}_{BB,2}$  under a tie,  $p_{n,1}^A = p_{n,1}^B = c$  constitutes a Nash equilibrium in period 1.

By the same argument as in the proof of Proposition 2, any price strategy pair such that  $p_{n,1}^A = p_{n,1}^B = p < c$  and  $p$  is sufficiently close to marginal cost, would also constitute a pure-strategy Nash equilibrium in period 1. I limit attention to the case where firms coordinate on the Pareto-optimal equilibrium point,  $p_{n,1}^A = p_{n,1}^B = c$ .

- (b) From Proposition 2 we see that a large shock in period 2 implies higher profits from loyal customers for firm B (because the rival's introductory price is higher and  $\partial p_o^B / \partial p_n^A > 0$ ) and also a larger loyal customer segment,  $\hat{q}_{BB,2} > \hat{q}_{BB}^*$ . On the other hand, firm A's profits from loyal customers will be lower, and its optimal market share,  $\hat{q}_{AA,2}$ , will be lower as well (and possibly zero if the cost shock is very large).

Consider again  $p_{n,1}^A = p_{n,1}^B = c$  and suppose that  $\hat{q}_{AA,2} + \hat{q}_{BB,2} \leq 1$ . Under the same sharing rule and arguments used in part (a),  $p_{n,1}^A = p_{n,1}^B = c$  is a Nash equilibrium in period 1 as long as the firms split the market such that  $x_2 = 1 - \hat{q}_{BB,2}$ . As long as A and B capture their future loyal customer segments,  $\hat{q}_{AA,2}$  and  $\hat{q}_{BB,2}$  respectively, while firm A also captures all customers in the range  $(\hat{q}_{AA,2}, 1 - \hat{q}_{BB,2})$ , then neither firm has an incentive to undercut or to raise its price above the rival's price.

The key condition here is that the firms' loyal customer segments do not overlap, i.e. it is necessary that  $\hat{q}_{AA,2} + \hat{q}_{BB,2} \leq 1$ . We can now show that this condition is always satisfied. Recall from Proposition 2 that firm B's equilibrium price in period 2 is given by  $p_n^* < p_{n,2}^B < \underline{p}^A$  where  $\underline{p}^A$  is firm A's break-even price while  $p_n^*$  is the price that optimizes firm B's profits from switchers and newcomers in period 2 and is bounded below by  $c$ . Consider the upper bound of  $p_{n,2}^B$ :  $\underline{p}^A$ . By plugging this equilibrium price in (3.2.13) and (3.2.14) to replace  $p_{nt}^B$  and  $p_{nt}^A$ , respectively, and using  $\tilde{c}$  to designate firm A's marginal cost in period 2, we can obtain  $\hat{q}_{AA,2}$  and  $\hat{q}_{BB,2}$  as functions of  $\underline{p}^A$ :

$$\hat{q}_{AA,2}(\underline{p}^A) = \frac{\tau + s + \underline{p}^A - \tilde{c}}{4\tau} \quad (\text{B.1.29})$$

$$\hat{q}_{BB,2}(\underline{p}^A) = \frac{\tau + s + \underline{p}^A - c}{4\tau} \quad (\text{B.1.30})$$

We can rewrite  $\hat{q}_{AA,2} + \hat{q}_{BB,2}$  as:

$$\hat{q}_{AA,2} + \hat{q}_{BB,2} = \frac{2\tau + 2s + 2\underline{p}^A - c - \tilde{c}}{4\tau} \quad (\text{B.1.31})$$

$$= \frac{2\tau + 2s + 2\underline{p}^A - 2c - \Delta c}{4\tau} \quad (\text{B.1.32})$$

$$= \frac{2\tau + 2s - 2\overline{\Delta c} - \Delta c}{4\tau} \quad (\text{B.1.33})$$

$$= 2 \frac{2\tau + 2s}{4\tau} - \frac{2\overline{\Delta c}}{4\tau} - \frac{\Delta c}{4\tau} \quad (\text{B.1.34})$$

The first term above is equal to the firms' optimal market share in steady state,  $q_{ii}^*$ , from Proposition 1. Therefore, we can rewrite

$$\hat{q}_{AA,2} + \hat{q}_{BB,2} = 2q_{ii}^* - \frac{\overline{\Delta c}}{2\tau} - \frac{\Delta c}{4\tau} \quad (\text{B.1.35})$$

which is always less than one because  $q_{ii}^* \leq 1/2$  since  $s \leq \tau$  while  $\Delta c$  and  $\overline{\Delta c}$  are positive. Note that  $\hat{q}_{AA,2} + \hat{q}_{BB,2} \leq 1$  is valid for any equilibrium introductory price below  $\underline{p}^A$  because  $\hat{q}_{ii,2}$  is increasing in  $p_{n,2}^j$ .

Similar to part (a), any price strategy pair such that  $p_{n,0}^A = p_{n,0}^B = p < c$  and  $p$  is sufficiently close to marginal cost, would also constitute a pure-strategy Nash equilibrium in period 0. Note that the lower bound on the price that would be a Nash equilibrium is constrained by the lowest price that firm A will accept to maintain because its future profits from market share are smaller. Hence, the range  $[\underline{p}, c]$ , within which identical prices constitute an equilibrium, is much smaller and can be the empty space if firm A does not retain any loyal customers

in period 1 (plausible if the cost shock is very large).

From the modification of the sharing rule,  $x_1 = 1 - \hat{q}_{BB,1}$  when  $p_n^A = p_n^B$ , it is clear that next period firm A will face no demand from switchers. As a result, firm A has no profitable deviation when it is outbid at  $p_{n,1}^B = \underline{p}^A - \epsilon$ . Recall from the proof of Proposition 2 that we had to derive  $\Delta c \geq \underline{\Delta}c$  as a necessary condition to ensure that firm A faces no demand from switchers at  $p_{n,1}^A = \underline{p}^A$  and a pure-strategy equilibrium exists. Now that the shock is anticipated, the equilibrium distribution of the market in the period preceding the shock guarantees that  $q_{BA,1} = 0$  and the equilibrium in part (b) of Proposition 2 applies as soon as  $\Delta c > \overline{\Delta}c$ . Hence, we can state that  $\overline{\Delta}c \equiv \underline{\Delta}c$  and conclude that in period 1, there exists a pure strategy equilibrium for all values of the cost shock.  $\square$

### B.1.7 Proof of Proposition 4

*Proof.* The proof is a straightforward result of Propositions 2 and 3. Define the strategic cost of information sharing for firm B as the net present value of the benefits that it will forgo as a result of revealing information to its rival when the latter has revealed information as well. Conditional on firm A's cost shock being small, i.e.  $\Delta c \leq \overline{\Delta}c$ , Propositions 2 and 3 demonstrate that firm B does not realize higher profits in period 1 ( $p_{n,1}^B = p_n^*$ ) or period 2 ( $p_{n,2}^B = p_n^*$ ) upon exposing firm A to a higher risk of default by withholding information. On the other hand, firm B realizes strictly higher profits when firm A's cost of funds is sufficiently high,  $\Delta c > \overline{\Delta}c$ , since firm B sells at a price above cost to all new customers in period

2 and also generates higher profits from loyal customers. These profits are not competed away in period 1 as demonstrated by Proposition 3.  $\square$

### B.1.8 Proof of Corollary 2

*Proof.* To sign the derivative of  $\overline{\Delta c}$  with respect to  $s$ , we need to modify the expression for  $\overline{\Delta c}$  from (B.1.18) to reflect the fact that in period 2 firm A faces no demand from switchers. Therefore, we rewrite (B.1.18) as:

$$F(\overline{\Delta c}) = (-\overline{\Delta c})\left(\frac{1}{2} + 0\right) + \delta_f \frac{(\tau + s)^2}{8\tau} + E - \left(\frac{\tau - s - \overline{\Delta c}}{2}\right) \cdot \max\left(\frac{\tau - s - \overline{\Delta c}}{8\tau}, 0\right) = 0 \quad (\text{B.1.36})$$

Since  $q_{BA}(\underline{p}^A) = 0$ , it follows that  $q_{BA} = 0$  for any price above  $\underline{p}^A$ . Therefore,  $\max\left(\frac{\tau - s - \overline{\Delta c}}{8\tau}, 0\right) = 0$  and (B.1.36) becomes:

$$F(\overline{\Delta c}) = (-\overline{\Delta c})\frac{1}{2} + \delta_f \frac{(\tau + s)^2}{8\tau} + E = 0 \quad (\text{B.1.37})$$

I apply the Implicit Function Theorem with respect to (B.1.36) to obtain  $\partial\overline{\Delta c}/\partial s$  and  $\partial\overline{\Delta c}/\partial\tau$ :



$$\frac{\partial \overline{\Delta c}}{\partial s} = -\frac{\partial F / \partial s}{\partial F / \partial \overline{\Delta c}} \quad (\text{B.1.38})$$

$$= -\frac{\frac{2\delta_f(\tau+s)}{8\tau}}{-1/2} \quad (\text{B.1.39})$$

$$= \frac{\delta_f(\tau+s)}{2\tau} \quad (\text{B.1.40})$$

$$> 0 \quad (\text{B.1.41})$$

$$\frac{\partial \overline{\Delta c}}{\partial \tau} = -\frac{\partial F / \partial \tau}{\partial F / \partial \overline{\Delta c}} \quad (\text{B.1.42})$$

$$= -\frac{\frac{\delta_f(2(\tau+s)8\tau - 8(\tau+s)^2)}{(8\tau)^2}}{-1/2} \quad (\text{B.1.43})$$

$$= -\frac{\frac{\delta_f(16\tau^2 + 16\tau s - 8\tau^2 - 16\tau s - 8s^2)}{(64\tau^2)}}{-1/2} \quad (\text{B.1.44})$$

$$= \delta_f \frac{8(\tau^2 - s^2)}{32\tau^2} \quad (\text{B.1.45})$$

$$\geq 0 \text{ since } s \leq \tau \quad (\text{B.1.46})$$

We can also obtain the cross-partial derivatives:

$$F_{s\tau} = F_{\tau s} = -\delta_f \frac{2s}{4\tau^2} \quad (\text{B.1.47})$$

□

## B.2 Tables

Table B.1: Variable Definitions.

Variable Name	Definition
age	traders's age
capital	=1 if the trader operates in the capital city, 0 otherwise
categ	firm category; =1 if wholesaler, =2 if semi-wholesaler; =3 if retailer with a fixed point of sale; =4 if retailer without a fixed points of sale; =5 if assembler for the manufacturing sector; =6 if assembler for the own purposes
discuss prices	=1 if the trader shares information about (input or output) prices at least once a month, 0 otherwise
discuss suppliers	=1 if the trader shares information about supplier quality at least once a month, 0 otherwise
HS education	educational level of the trader; =1 if trader has at least high-school education, 0 otherwise
family members with jobs	=0 if the respondent has no family members with salary jobs; =1 if 1 – 2 family members with jobs; = 2 if > 2 family members with jobs
firm age	age of the firm: =1 if < 5 years, =2 if 5 – 10 years, =3 if > 10 years
main product	main product traded: 1-rice, 2-tapioca, 3-corn, 4-beans, 5-sweet potatoes, 6-peanuts
product processing region	=1 if the trader processes the product as a secondary activity, 0 otherwise geographic region: 1-Tana Hauts Plateaux, 2-Vakinankaratra, 3-Fianar Hauts Plateaux, 4-Fianar Côte et falaise, 5-Majunga Plaines, 6-Majunga Hauts Plateaux
sex	=1 if trader is male, 0 otherwise
sizecat	firm size category: =1 if small, =2 if medium, =3 if large
shares info	=1 if the trader shares information about delinquent customers at least once a month, 0 otherwise
strong competition	=1 if the trader perceives the level of competition as strong, 0 otherwise
telephone access	=1 if the trader has access to a telephone, 0 otherwise
traders known	# other traders the respondent knows personally; =1 if the trader knows < 4 traders, =2 if 4 – 9 traders, and =3 if 10 or more traders

Table B.2: Liquidity Scores Components.

Liquidity Specification	Dummy Variables Used	Liquidity Score (LS) Range
LS 1	can borrow from friends/family has 1 – 3 family members/friends to borrow from has > 3 family members/friends to borrow from has 1 – 2 family members with jobs has > 2 family members with jobs	0 to 5
LS 2	has formal savings has informal savings has bank account has another source of income has overdraft facility	0 to 5

Table B.3: Frequency distribution of Own Liquidity Score 1.

LS 1	Freq.	Percent	Cum.
0	5	1.63	1.63
1	16	5.21	6.84
2	82	26.71	33.55
3	90	29.32	62.87
4	82	26.71	89.58
5	32	10.42	100.00
Total	307	100	

Table B.4: Frequency distribution of Own Liquidity Score 2.

LS 2	Freq.	Percent	Cum.
0	81	26.56	26.56
1	114	37.38	63.93
2	83	27.21	91.15
3	27	8.85	100.00
Total	305	100	

Table B.5: Frequency distribution of Average Liquidity Scores.

Variable	Obs	Mean	Std. Dev.	Min	Max	Median
Avg. Liq. Score 1	299	3.031	.352	1.5	4	3.018
Avg. Liq. Score 2	299	1.156	.320	0	3	1.222

Table B.6: Summary Statistics. IS stands for information sharing. Significance level of differences in means across the two samples are indicated as follows: \*\*\* indicate significance at the 1% level, \*\* – significance at the 5% level, and \* – significance at the 10% level.

Variable	All		No IS		IS		
	Mean	Obs.	Mean	Obs.	Mean	Obs.	
Information sharing (IS)	0.132	304	0	264	1	40	
Age	38.96	300	38.96	260	39.86	40	
Sex	0.587	300	0.585	260	0.6	40	
HS education	0.046	304	0.042	264	0.075	40	
Wholesaler	0.267	303	0.274	263	0.225	40	
Semi-wholesaler	0.125	303	0.125	263	0.125	40	
Retailer w/ fixed selling point	0.436	303	0.418	263	0.55	40	
Retailer w/o fixed selling point	0.036	303	0.042	263	0	40	
Assembler manufacturing	0.026	303	0.027	263	0.025	40	
Assembler private use	0.106	303	0.11	263	0.075	40	
Assembler hired	0.003	303	0.004	263	0	40	
Firm age: < 5 yrs	0.322	304	0.333	264	0.25	40	
Firm age: 5 – 10 yrs	0.497	304	0.492	264	0.525	40	
Firm age: > 10 yrs	0.181	304	0.174	264	0.225	40	
Main Product: Rice	0.75	304	0.784	264	0.525	40	***
Main Product: Tapioca	0.046	304	0.045	264	0.05	40	
Main Product: Corn	0.016	304	0.015	264	0.025	40	
Main Product: Beans	0.118	304	0.102	264	0.225	40	*
Main Product: Potatoes	0.026	304	0.023	264	0.05	40	
Main Product: Peanuts	0.043	304	0.03	264	0.125	40	**
Traders known: < 4	0.08	303	0.072	263	0.1	40	
Traders known: 4 – 9	0.396	303	0.384	263	0.475	40	
Traders known: > 9	0.528	303	0.544	263	0.425	40	
Small firm	0.15	301	0.169	261	0.025	40	*
Medium-sized firm	0.342	301	0.326	261	0.45	40	
Large firm	0.508	301	0.506	261	0.525	40	
Capital region	0.214	304	0.2	264	0.325	40	
Region:							
Tana Hauts Plateaux	0.248	303	0.232	263	0.35	40	
Vakinankaratra	0.274	303	0.289	263	0.175	40	
Fianar Hauts Plateaux	0.281	303	0.278	263	0.3	40	
Fianar Cte et falaise	0.149	303	0.144	263	0.175	40	
Majunga Plaines	0.013	303	0.015	263	0	40	
Majunga Hauts Plateaux	0.036	303	0.042	263	0	40	
Telephone access	0.508	303	0.513	263	0.475	40	
Discusses suppliers	0.244	303	0.205	263	0.5	40	***
Discusses prices	0.322	304	0.25	264	0.8	40	***
Processing products	0.083	303	0.087	263	0.05	40	
% sales to reg. customers	36.753	304	37.682	264	30.625	40	
% credit sales	30.987	304	31.64	264	26.675	40	
Strong competition	0.759	303	0.745	263	0.85	40	
Liquidity score 1	3.049	304	3.011	264	3.3	40	
Liquidity score 2	1.185	302	1.156	262	1.375	40	

Table B.7: Controls.

Group	Control variables
Market and Demographic Characteristics	trader's age education sex firm age firm size trade category product region number of traders known capital telephone
Competition	strong competition log(% of sales to regular clients) product processing
Additional controls	log(% of credit sales) discusses suppliers discusses prices

Table B.8: Determinants of Competition Intensity. Probit estimates; the dependent variable is a dummy equal to one if the trader reports strong market competition. All regressions control for the market and demographic characteristics listed in Table B.7. Coefficients reported, robust standard errors in parentheses. \*\*\* indicate significance at the 1% level, \*\* – significance at the 5% level, and \* – significance at the 10% level.

<b>Dep. Variable: Strong Competition</b>	(1)	(2)	(3)	(4)	(5)	(6)	(7)
HS education	-1.285*** (0.434)	-1.309*** (0.430)	-1.299*** (0.437)	-1.278*** (0.417)	-1.249*** (0.451)	-1.339*** (0.431)	-1.450*** (0.433)
Processing	-0.629 (0.422)	-0.629 (0.423)	-0.633 (0.426)	-0.619 (0.421)	-0.552 (0.418)	-0.723* (0.438)	-0.693 (0.437)
Log(sales to regular customers)	-0.409** (0.165)	-0.373** (0.184)	-0.408** (0.165)	-0.421** (0.167)	-0.396** (0.162)	-0.441*** (0.169)	-0.435** (0.194)
Log(% credit sales)		-0.071 (0.175)					-0.048 (0.179)
Discuss prices			-0.027 (0.244)				0.016 (0.254)
Discuss suppliers		0.018 (0.253)				-0.099 (0.279)	
Liquidity Score 1 = 2				-0.933* (0.531)			-0.926* (0.476)
Liquidity Score 1 = 3				-1.111** (0.510)			-1.194*** (0.445)
Liquidity Score 1 = 4				-0.964* (0.536)			-1.013** (0.491)
Liquidity Score 1 = 5				-0.821 (0.565)			-0.794 (0.520)
Liquidity Score 2 = 1					-0.216 (0.275)		
Liquidity Score 2 = 2					0.141 (0.332)		
Liquidity Score 2 = 3					-0.314 (0.385)		
6 – 10 competitors						-0.358 (0.405)	-0.605 (0.423)
11 – 15 competitors						0.390 (0.979)	0.029 (0.868)
> 15 competitors						0.455 (0.687)	0.322 (0.669)
Unknown # competitors						-0.127 (0.246)	-0.190 (0.253)
Observations	273	273	271	273	272	273	271
$\chi^2$	69.14	71.02	71.61	77.80	73.33	71.74	83.83

Table B.9: Probit estimates. All regressions control for the market and demographic characteristics listed in Table B.7. Coefficients reported, robust standard errors in parentheses. \*\*\* indicate significance at the 1% level, \*\* – significance at the 5% level, and \* – significance at the 10% level.

Dep. Var.: IS	(1)	(2)	(3)	(4)	(5)	(6)
Strong Competition	0.478* (0.280)	0.794** (0.388)	0.789* (0.428)	0.767* (0.415)	0.925** (0.385)	0.804** (0.400)
Semi-wholesaler	0.507 (0.375)	1.160** (0.545)	1.401** (0.601)	1.304** (0.604)	1.338** (0.591)	0.723 (0.575)
Retailer with fixed selling point	0.810*** (0.306)	1.105** (0.520)	1.392*** (0.539)	1.361** (0.617)	1.565*** (0.588)	0.596 (0.536)
Assembler manufacturing	0.674 (0.589)	-0.094 (0.881)	-0.326 (0.888)	0.207 (0.990)	0.232 (0.891)	-0.171 (0.936)
Assembler individual	0.414 (0.419)	0.797 (0.663)	1.185* (0.646)	1.178 (0.764)	1.398* (0.747)	0.396 (0.705)
Firm Age: 5 – 10 yrs	0.469 (0.295)	0.745* (0.425)	0.682 (0.443)	0.825* (0.447)	0.654 (0.421)	0.694 (0.434)
Firm Age: > 10 yrs	0.304 (0.334)	0.538 (0.446)	0.404 (0.452)	0.352 (0.430)	0.684 (0.463)	0.640 (0.451)
Medium-sized firm	1.456*** (0.533)	2.232*** (0.656)	2.381*** (0.633)	2.732*** (0.655)	2.396*** (0.615)	2.309*** (0.675)
Large firm	1.073** (0.520)	1.793*** (0.674)	2.056*** (0.672)	2.149*** (0.632)	1.852*** (0.627)	1.769** (0.690)
4 – 9 traders known	-0.338 (0.447)	-0.198 (0.479)	-0.123 (0.444)	-0.168 (0.587)	-0.068 (0.527)	-0.275 (0.490)
> 9 traders known	-0.392 (0.448)	-0.863 (0.530)	-0.798* (0.481)	-0.738 (0.616)	-0.842 (0.609)	-0.979* (0.563)
Capital region	0.048 (0.553)	1.329 (0.900)	1.648* (0.979)	2.097* (1.113)	1.313 (0.966)	1.527 (0.931)
Telephone access	-0.322 (0.273)	-0.366 (0.304)	-0.423 (0.303)	-0.379 (0.356)	-0.345 (0.324)	-0.381 (0.313)
Processing		0.599 (0.717)	0.897 (0.689)	0.974 (0.828)	0.683 (0.750)	0.504 (0.788)
Log(% sales to regular customers)		-0.417 (0.276)	-0.281 (0.290)	-0.522* (0.306)	-0.697** (0.306)	-0.540* (0.288)
Discuss prices		2.050*** (0.369)	2.168*** (0.394)	2.346*** (0.406)	2.291*** (0.388)	2.090*** (0.382)
Discuss suppliers		0.223 (0.338)	0.375 (0.331)	0.320 (0.364)	0.174 (0.346)	0.251 (0.335)
Log(% credit sales)		0.226 (0.262)	0.038 (0.260)	0.208 (0.259)	0.465 (0.301)	0.378 (0.279)
Liquidity Controls:						
Own Liq. Score 1			Y			
Own Liq. Score 2				Y		
Avg. Liq. Score 1					Y	
Avg. Liq. Score 2						Y
Observations	277	253	253	253	253	253
$\chi^2$	39.75	99.76	125.46	111.20	93.84	98.91



Table B.10: Probit estimates of the probability of sharing information using Liquidity Score 1. All regressions control for the market and demographic characteristics listed in Table B.7. Coefficients reported, robust standard errors in parentheses. \*\*\* indicate significance at the 1% level, \*\* – significance at the 5% level, and \* – significance at the 10% level.

Dep. Var.: IS	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<i>Panel A</i>							
Own Liq. Score 1 = 2	-0.911** (0.437)	-0.953** (0.427)	-0.853* (0.439)	-1.152** (0.458)	-1.001** (0.490)	-1.075** (0.526)	-1.026* (0.573)
Own Liq. Score 1 = 3	-0.007 (0.425)	-0.011 (0.421)	0.074 (0.427)	-0.281 (0.457)	0.028 (0.474)	0.078 (0.514)	-0.041 (0.612)
Own Liq. Score 1 = 4	-0.491 (0.465)	-0.489 (0.457)	-0.425 (0.462)	-0.764 (0.502)	-0.214 (0.538)	-0.162 (0.569)	0.124 (0.623)
Own Liq. Score 1 = 5	0.082 (0.495)	0.101 (0.494)	0.123 (0.495)	-0.165 (0.512)	0.757 (0.523)	0.853 (0.590)	0.785 (0.664)
Observations	279	279	279	254	279	254	198
$\chi^2$	59.70	59.76	61.45	65.58	106.38	125.90	103.28
<i>Panel B</i>							
Own Liq. Score 2 = 1	0.163 (0.285)	0.181 (0.277)	0.192 (0.281)	0.264 (0.281)	-0.553 (0.415)	-0.378 (0.416)	-1.016** (0.472)
Own Liq. Score 2 = 2	0.813** (0.339)	0.825** (0.331)	0.796** (0.339)	0.907*** (0.329)	0.719 (0.440)	0.798* (0.434)	0.499 (0.548)
Own Liq. Score 2 = 3	0.912** (0.463)	0.925** (0.458)	0.967** (0.464)	1.092** (0.486)	0.826 (0.564)	1.122* (0.597)	0.548 (0.725)
Observations	278	278	278	253	278	253	198
$\chi^2$	48.54	47.59	48.83	59.15	93.93	111.20	100.37
<i>Panel C</i>							
Own Liq. Score 1 > 2	0.553** (0.256)	0.575** (0.258)	0.576** (0.254)	0.478* (0.276)	0.812*** (0.306)	0.887*** (0.319)	0.887*** (0.331)
Observations	279	279	279	254	279	254	198
$\chi^2$	44.73	43.84	47.90	51.41	96.89	112.51	89.70
<i>Panel D</i>							
Own Liq. Score 2 > 1	0.725*** (0.250)	0.725*** (0.249)	0.706*** (0.251)	0.764*** (0.258)	1.039*** (0.345)	1.105*** (0.331)	1.103*** (0.418)
Observations	279	279	279	254	279	254	198
$\chi^2$	47.88	47.42	48.45	60.41	93.82	101.90	87.48
<i>Panel E</i>							
Avg Liq. Score 1	-0.026 (0.438)	-0.053 (0.440)	0.404 (0.427)	0.244 (0.438)	0.017 (0.440)	1.135** (0.485)	1.484*** (0.560)
Observations	277	277	277	253	277	253	198
Chi2	39.45	38.73	93.26	47.77	39.82	93.84	85.71
<i>Panel F</i>							
Avg Liq. Score 2	1.279* (0.663)	1.273* (0.679)	1.137** (0.574)	1.053* (0.633)	1.163* (0.619)	1.100* (0.588)	1.219** (0.584)
Observations	277	277	277	253	277	253	198
Chi2	41.41	40.73	95.17	48.26	42.42	98.91	101.90
Controls:							
Market/ Demographics	Y	Y	Y	Y	Y	Y	Y
Log(% credit sales)		Y				Y	Y
Strong Competition			Y			Y	Y
Processing / to regular customers)				Y		Y	Y
Discuss prices / Discuss suppliers					Y	Y	Y
Suppliers will not extend credit to delinquent customers							Y

Table B.11: Robustness Checks – probit estimates of the probability of sharing information. All regressions control for the market and demographic characteristics listed in Table B.7, except that in column (2) we replace the regional FE with city FE. Coefficients reported, robust standard errors in parentheses. \*\*\* indicate significance at the 1% level, \*\* – significance at the 5% level, and \* – significance at the 10% level.

Dependent Variable: IS	Baseline (1)	City FE (2)	15 – 50% Credit Sales (3)	Past Default (4)
<i>Panel A</i>				
Own Liq. Score 1 = 2	-1.075** (0.526)	-7.153*** (2.180)	-1.382** (0.573)	-1.596** (0.720)
Own Liq. Score 1 = 3	0.078 (0.514)	-1.744 (1.146)	-0.136 (0.582)	-0.107 (0.513)
Own Liq. Score 1 = 4	-0.162 (0.569)	-0.673 (1.125)	-0.412 (0.671)	-1.056 (0.733)
Own Liq. Score 1 = 5	0.853 (0.590)	1.516 (1.411)	0.797 (0.662)	-0.495 (0.771)
Observations	254	158	233	152
$\chi^2$	125.90	58.27	116.09	59.55
<i>Panel B</i>				
Own Liq. Score 2 = 1	-0.378 (0.416)	-0.133 (0.680)	-0.378 (0.455)	-0.642 (0.692)
Own Liq. Score 2 = 2	0.798* (0.434)	2.266** (0.882)	1.073** (0.491)	1.593** (0.694)
Own Liq. Score 2 = 3	1.122* (0.597)	1.475 (0.903)	1.314** (0.573)	2.206** (0.911)
Observations	253	157	232	152
$\chi^2$	111.20	90.75	97.87	63.13
<i>Panel C</i>				
Own Liq. Score 1 > 2	0.887*** (0.319)	3.457*** (1.113)	0.867** (0.378)	0.700* (0.376)
Observations	253	157	232	152
$\chi^2$	111.85	57.82	103.48	67.52
<i>Panel D</i>				
Own Liq. Score 2 > 1	1.105*** (0.331)	2.129*** (0.560)	1.377*** (0.368)	2.007*** (0.572)
Observations	253	157	232	152
$\chi^2$	100.71	86.82	84.11	60.32
<i>Panel E</i>				
Avg Liq. Score 1	1.135** (0.485)	1.426 (0.922)	1.201** (0.512)	0.914 (0.612)
Observations	253	157	232	152
Chi2	93.84	88.29	90.82	67.64
<i>Panel F</i>				
Avg Liq. Score 2	1.100* (0.588)	2.810*** (0.846)	1.330** (0.602)	0.984 (0.848)
Observations	253	157	232	152
Chi2	98.91	81.87	97.85	70.81

Table B.12: Ordered probit estimates. Columns report estimates for the own and average market liquidity. All regressions control for the market and demographic characteristics listed in Table B.7. Coefficients reported, robust standard errors in parentheses. \*\*\* indicate significance at the 1% level, \*\* – significance at the 5% level, and \* – significance at the 10% level.

Dep. Var.: IS	Liquidity Variables			
	(1)	(2)	(3)	(4)
Own Liq. Score 1 = 2	0.190 (0.327)			
Own Liq. Score 1 = 3	0.435 (0.322)			
Own Liq. Score 1 = 4	-0.058 (0.361)			
Own Liq. Score 1 = 5	0.890** (0.453)			
Own Liq. Score 2 = 1		-0.162 (0.213)		
Own Liq. Score 2 = 2		0.076 (0.256)		
Own Liq. Score 2 = 3		0.227 (0.347)		
Avg Liq. Score 1			0.113 (0.306)	
Avg Liq. Score 2				0.778** (0.348)
Log(% credit sales)	0.065 (0.137)	0.125 (0.130)	0.128 (0.129)	0.141 (0.126)
Processing	0.323 (0.306)	0.275 (0.316)	0.328 (0.306)	0.304 (0.315)
Log(% sales to regular customers)	0.140 (0.158)	0.068 (0.153)	0.052 (0.152)	0.066 (0.151)
Discuss prices	1.552*** (0.247)	1.430*** (0.224)	1.455*** (0.225)	1.457*** (0.229)
Discuss suppliers	0.044 (0.226)	0.274 (0.205)	0.200 (0.202)	0.221 (0.201)
Strong Competition	0.020 (0.176)	-0.035 (0.178)	-0.016 (0.174)	-0.044 (0.176)
Semi-wholesaler	0.193 (0.280)	0.123 (0.261)	0.112 (0.264)	-0.115 (0.278)
Retailer with fixed selling point	0.290 (0.224)	0.215 (0.221)	0.239 (0.236)	-0.134 (0.261)
Assembler manufacturing	-0.603 (0.545)	-0.578 (0.533)	-0.675 (0.508)	-0.682 (0.518)
Assembler individual	0.104 (0.287)	0.026 (0.278)	0.064 (0.304)	-0.251 (0.305)
Firm Age: 5 – 10 yrs	0.059 (0.229)	0.015 (0.216)	0.014 (0.213)	0.008 (0.212)
Firm Age: > 10 yrs	-0.332 (0.253)	-0.247 (0.242)	-0.206 (0.239)	-0.182 (0.244)
Medium-sized firm	0.110 (0.231)	0.109 (0.234)	0.128 (0.227)	0.169 (0.229)
Large firm	0.432** (0.208)	0.397* (0.216)	0.422** (0.209)	0.431** (0.211)
4 – 9 traders known	-0.193 (0.325)	-0.161 (0.313)	-0.177 (0.306)	-0.202 (0.306)
> 9 traders known	-0.277 (0.307)	-0.290 (0.289)	-0.310 (0.278)	-0.341 (0.277)
Observations	270	270	270	270
Chi2	132.52	146.62	124.80	145.02

Table B.13: Average marginal effects of liquidity. Estimates are based on column (6) of Table B.10

	Avg. Marginal Effect	St. Error	Z-stat	P-value
Own Liq. Score 1 > 2	0.097	0.032	3.00	0.003
Own Liq. Score 2 > 1	0.130	0.038	3.43	0.001
Avg. Liq. Score 1	0.086	0.052	1.66	0.096
Avg. Liq. Score 2	0.173	0.065	2.66	0.008

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