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Cards on the table: efficiency and welfare effects of the No-Surcharge Rule*

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Abstract

In Electronic Payment Networks (EPNs), the No-Surcharge Rule (NSR) requires that merchants charge at most the same amount for a payment card transaction as for cash. In this paper, I use a three-party model (consumers, local monopolistic merchants, and a proprietary EPN) with endogenous transaction volumes, heterogeneous card use benefits for merchants and network externalities of card-accepting merchants on cardholders to assess the efficiency and welfare effects of the NSR. I show that the NSR: (i) promotes retail price efficiency for cardholders, and (ii) inefficiently reduces card acceptance among merchants. The NSR can enhance social welfare and improve payment efficiency by shifting output from cash payers to cardholders. However, if network externalities are sufficiently strong, the reduction of card payment acceptance affects cardholders negatively and, with the exception of the EPN, all agents will be worse off under the NSR. This paper also suggests that the NSR may be an instrument to decrease cash usage, but the social optimal policy on the NSR may depend on the competitive conditions in each market.

Keywords: Competition, Electronic Payment Networks, Market Power, Network Externalities, No-Surcharge Rule, Regulation, Two-sided Markets.

JEL: G21, L14, L42.

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1 Introduction

Motivation. Payment cards[1] have been experiencing fast growth which has drawn attention to some of the contentious features of this industry such as the No-Surcharge Rule (NSR).[2] The NSR means that a merchant charges at most the same amount for a payment card transaction as for cash.[3] Electronic Payment Networks (EPNs) have argued that to gain greater merchant acceptance and consumer usage such a rule is necessary. But is this an efficient and welfare-enhancing rule?

In several countries, the NSR has been under examination by regulatory and competition authorities, central banks, courts and governments. For example, in 2010 the Portuguese Government decided to make the NSR mandatory by law, claiming consumer protection and that the use of electronic payments is more efficient than cash, thus should be protected. In the same year, Visa and MasterCard reached a settlement with the US DOJ allowing merchants to reward consumers for paying with cards with lower merchant fees associated, while American Express Co. (AmEx) vowed to fight a Government antitrust lawsuit (Forden and Eichenbaum, 2010). In 2015, a US District Court judge sided with the DOJ, ruling that AmEx's rules were anticompetitive by not allowing merchants to promote other cards or offer certain discounts (Sidel, 2015). Note, however, that cash discounts have been used in some circumstances (Barron et al., 1992). In the UK, in 2013 the Government banned payment card surcharges by some businesses such as airlines, cinemas and hotels, as a means to protect consumers from paying excessive card transaction fees (BBC News, 2013). Also, in early 2018, a ban on payment card surcharges came into effect across the EU (Financial Times, 2018). In other countries, such as Australia, the NSR has been abolished (Reserve Bank of Australia, 2011). Critics of the NSR have claimed that it inefficiently encourages the use of more costly forms of payment (e.g. credit cards) over the less costly (e.g. cash) leading to a "*Gresham's Law of Payments*".

Related literature. Formal economic analysis of electronic payment sys-

[1] The payment cards industry includes credit, debit, and prepaid cards. In this paper, I will focus on those with rewards programs attached. Examples of rewards comprise cashback and points which can be exchanged for goods or services. The rewards may also be construed as the features coupled with card usage such as theft-insurance for goods purchased with the card, or dispute-resolution protection.

[2] In 2002, transactions done on electronic payment networks in the US exceeded \$1.7 trillion (Schwartz and Vincent, 2006). In 2006, payment cards were used in 47 billion transactions for a total of \$3.1 trillion (Shy and Wang, 2011). In 2008, debit and prepaid card purchases topped \$3.3 trillion (almost a quarter of US GDP). In the UK it is expected that consumer card usage will rise by 75% from nearly 10 billion payments in 2012 to nearly 17 billion in 2022 (`http://www.paymentscouncil.org.uk`).

[3] Although infrequent, there have been cases where card payments were discounted relatively to cash. For example, in Germany during the transition from mark to euro currency, and in Argentina and Colombia the Governments have been offering VAT discounts to debit and credit card transactions since 2003.

tems was initiated by Baxter (1983) with an analysis of the National Bancard Corporation vs Visa US Inc litigation (Frankel and Shampine, 2006). Since then the theoretical payment card literature has been growing, especially after the year 2000, by addressing the issue of how costs of payment cards are and might be divided among EPNs, merchants and cardholders (Rochet and Tirole, 2002, 2003, 2006; Cabral, 2006; Wright, 2012).[4] This literature has pointed out that EPNs may charge fees significantly in excess of their costs to merchants and provide incentives to cardholders to increase card adoption and usage. Nonetheless, to a significant extent, this literature has assumed that the NSR is in force.

Wright (2003) analyzed the welfare effects of the NSR under two extremes of merchant competition: monopoly and Bertrand competition. He showed that if merchants are local monopolists, the NSR prevents them from surcharging excessively, therefore the NSR may increase social surplus. If merchants compete *à la* Bertrand, they pass to consumers the full benefits and costs associated with the payment instruments. Under the NSR, competitive merchants accept only cash or only card payments, and prices in the goods market are set at the respective marginal cost net of benefits. Under surcharging, competitive merchants accept both types of payment and price discriminate. Thus, if merchants compete *à la* Bertrand, the social surplus does not change regardless of the NSR. However, Wright (2003) as all other literature, with the exception of Schwartz and Vincent (2006), considered that the total quantity of goods purchased is fixed regardless of the NSR.

Schwartz and Vincent (2006) investigated the NSR welfare distribution effects among cash users and cardholders when a merchant is a local monopolist. The authors allowed for an elastic demand in the goods market, but assumed that consumers are exogenously divided into two groups: (i) cardholders that cannot use cash, and (ii) cash users. They concluded that the NSR harms both cash users and merchants, benefits cardholders, and is profitable to the EPN. However, their model assumes a single merchant and therefore does not take into account the NSR impact on the network size of card-accepting merchants.

Description of the paper. The analysis in this paper is based on a three-party model with consumers, merchants and an EPN.[5] The model differs from the existing literature at least in two main aspects. First, it considers simultaneously elastic demands in the acceptance of card payments, and goods market. This allows us to study the NSR effects on merchant acceptance and

[4] See Chakravorti (2010) for an excellent review of the growing payment card literature and discussion of the impact of regulatory interventions on card adoption, usage, and welfare. See Murphy and Ott (1977) and Carlton and Frankel (1995) for background on the institutional literature on NSRs.

[5] The analysis primarily addresses a closed network, but it may also characterize a four-party network if acquirers (issuers) are identical and perfectly competitive, while issuers (acquirers) are identical and collude when setting the fees to cardholders (merchants). One advantage of a three-party model is that the interchange fee does not need to be modeled, which in a four-party setup compensates the issuing bank each time cardholders use a card in a purchase.

quantity of goods transacted. Second, it considers positive network effects of card-accepting merchants on cardholders which, with very few exceptions (Economides and Henriques, 2011), have not been modelled in previous articles on the NSR.

This paper contributes to the study of the economic (in)efficiencies entailed by the NSR and highlights the: (i) improvement in retail price efficiency for cardholders, and (ii) inefficiency in merchant acceptance of card payments. Under the NSR, cardholders pay lower prices (closer to marginal cost) at card-accepting merchants, which improves price efficiency for card transactions, while cash payers pay higher prices. A relevant aspect in the model is that converting payments from cash to card generates cost savings for merchants. Thus, the NSR can improve payment efficiency and social welfare by shifting output from cash payers to cardholders, and may be an instrument to decrease cash usage. Nonetheless, if network effects are sufficiently strong, with the exception of the EPN, all groups of agents (cash payers, cardholders and merchants), and society as a whole, will be worse off under the NSR. This is because the network size of card-accepting merchants matters to cardholders and under the NSR fewer merchants are willing to accept card payments given their inability to price discriminate, while cash payers face higher retail prices.

The rest of the paper is organized as follows. Section 2 introduces the model to compare the equilibrium when merchants are allowed to surcharge card payments against the equilibrium under the NSR. Section 3 sets out the social optimum as a benchmark. Section 4 shows the equilibrium when merchants are allowed to surcharge card payments. Section 5 shows the equilibrium under the NSR. Section 6 analyzes the welfare variations and efficiency effects as a result of the NSR implementation. Section 7 concludes the paper. Proofs can be found in the Appendix.

2 The model

This section sets out a model with two payment instruments (cash and cards), characterizes each participating agent (consumers, merchants and a proprietary EPN) and describes how they interact in a sequential game. Cash is the default payment instrument, accessible to all consumers and merchants at no cost. As compared to cash, the EPN offers a service for electronic payments that may yield positive benefits for consumers and merchants. The elements of the model are as follows.

Consumers. There is a mass one of consumers split into two types: E-type (cardholders able to make electronic transactions) and C-type (cash payers).[6]

[6] In the US the fraction of households with a credit card has been steady at about 70 to 75% during the past two decades suggesting the maturity of the market (Schuh, Shy and Stavins, 2010). About 24% of US households do not hold cards of any kind (Schwartz and Vincent, 2006). These families may be unable to get payment cards or have a preference for anonymity when making a transaction.

E-type consumers have mass $\alpha \in (0, 1)$ and can pay for goods using either cash or card from an EPN.[7] C-type consumers, with mass $1 - \alpha$, can only purchase goods using cash payments.[8] The demand for a good per cash payer is

$$q_c(p_c) \equiv v - p_c, \tag{1}$$

where $v > 0$ is the consumers' maximal willingness to pay for the good itself, and p_c is the unit price for a cash payer. The consumer surplus per cash payer is then given by $CS_c \equiv \int_{p_c}^{v} q_c(x)\,dx$. When using a payment card, the demand for a good per cardholder is

$$q_e(p_e) \equiv v + r - p_e, \tag{2}$$

where p_e is the unit price with a card payment, and $r \geq 0$ is a reward per unit purchased. Rewards can be thought of as a negative price of card use, e.g. taking the form of direct monetary rebates (cashback), or goods, such as frequent flyer points. The consumer surplus per cardholder paying with card is then given by $CS_e \equiv \int_{p_e}^{v+r} q_e(x)\,dx$. If a cardholder purchases a good with cash, e.g. because the merchant accepts only cash, the demand in that instance (at that specific merchant) is given by (1), rather than (2). For simplicity, consumers can choose how to finance their purchases independently of the payment instrument, i.e. any cash payer or cardholder may negotiate loans directly with merchants or any financial institutions. Alternatively, if a rent is generated for the EPN in terms of interest charged on credit to cardholders, then r may be interpreted as rewards net of rents.[9]

Each consumer buys from every merchant (described further below), and cardholders care about the network size of card-accepting merchants. In particular, the larger the network of card-accepting merchants, the bigger the benefit of holding a payment card (network effect). A reason for this may be the security of paying by card, rather than cash. If cash is stolen, it is unlikely to be recovered. Whereas if a payment card is stolen, the cardholder can cancel the card immediately before fraudulent purchases are made. Moreover, EPNs have sophisticated safeguards (e.g. real time active fraud detection system, chip & PIN authentication) in place to protect cardholders in the event of unauthorized use. Thus, a larger merchant acceptance may lead cardholders to carry a smaller amount of cash. Also, access to cash may imply a cost, e.g. time and fees to withdraw cash from banks. Let $D \geq 0$ denote the network size of card-accepting merchants, and $b_B \geq 0$ the benefit brought to a cardholder

[7] Cashless payments represent 92% of transactions in France, 89% in the UK, 62% in Japan and 31% in Russia (MasterCard, 2013).

[8] Cash payments represent 45% of transactions in China and 20% in the US. Only 14% of payments made in Australia are cash, while in Egypt cash represents 93% of transactions. Worldwide, around 85% of all retail payment transactions are done with cash (MasterCard, 2013).

[9] See Agarwal, Chakravorti and Lunn (2010), Chakravorti and Emmons (2003), and Chakravorti and To (2007) for discussions on credit cards and empirical support that banks may use rewards to steal customers and their outstanding debt from other cards. In this model, I abstract from business stealing between banks treating that aspect independently of the NSR effects.

by the marginal card-accepting merchant. Thus, the term $b_B D$, in addition to the total consumer surplus per cardholder, measures the benefit from accessing a card acceptance network of D merchants. Note that b_B is unrelated to consumers' willingness to pay (demand) for the goods themselves.

Merchants. There is a mass one of merchants, each of whom is a profit-maximizing local monopolist supplying an independent good. A monopoly provides a first-order approximation to markets where merchants have market power. Such a market structure facilitates the welfare analysis of the NSR as it filters out strategic effects that typically arise in oligopolies. Wright (2004) addressed the case of Hotelling competition between merchants, however considering inelastic consumer demand. In such a case, card-accepting merchants are able to attract additional customers from rivals who accept cash only, but this effect is regardless of the NSR.

The marginal cost of producing a good is c, where $0 < c < v$. Merchants bear a fee $m \geq 0$ as a supply cost per card payment, while not facing explicit costs for cash payments. They have heterogeneous card use benefits, b_S per card payment, where b_S is uniformly distributed on $\left[0, \bar{b}_S\right]$. Merchants know their own b_S which reflects a benefit from cash-handling cost reduction or increased payment security compared to cash. The EPN knows the distribution of b_S but not the transactional benefit from card acceptance for individual merchants. I assume that: (i) $\bar{b}_S \leq c$, otherwise the net marginal cost of a card transaction $(c - b_S)$ would be negative for merchants with b_S sufficiently high; and (ii) $\bar{b}_S \leq v - c$ to ensure that cash payers are served in equilibrium when the NSR is in place.

The profit of a merchant with benefit b_S is $(p_e - c + b_S - m)\, q_e(p_e)$ per cardholder paying with card and $(p_c - c)\, q_c(p_c)$ per cash payer, where $q_e(p_e)$ and $q_c(p_c)$ are defined by (2) and (1), respectively. Assuming that cardholders pay with card whenever possible, which will be verified in equilibrium, for given values of (m, r), a merchant's profit is

$$\Pi(b_S) = \begin{cases} (p_c - c)(v - p_c) & \text{if only cash} \\ \alpha(p_e - c + b_S - m)(v + r - p_e) + (1-\alpha)(p_c - c)(v - p_c) & \text{if cash and card} \end{cases}. \tag{3}$$

All merchants must accept cash due to its status as legal tender, but will accept card payments if and only if accepting cash and card is at least as profitable as accepting only cash. In this model, the incentives for a merchant to accept card payments are: (i) benefits from card use b_S, and (ii) higher demand for goods from cardholders (depending on card rewards r). Another reason why a merchant may accept card payments is "business stealing". However, since by assumption merchants are local monopolists, such an effect is disregarded in this model.

Electronic Payment Network. Economides (2009) compared the NSR to a most-favored customer clause which can be used to increase the fees to collusive levels across the EPNs. To abstract away from strategic (anti-competitive) effects that may be introduced by the NSR, consider that there is only one profit-maximizing EPN. Although the monopoly case does not occur in practice, Cabral (2006) suggested that it may "provide a good first-order approximation to the reality of a number of countries", and the assumption has been used in the literature, e.g. Schwartz and Vincent (2006).

The EPN charges a merchant fee, m, per card payment while simultaneously financing a reward, r, to the cardholder. Hence, the EPN must choose $m \geq r$, otherwise it would have negative profit. A card payment requires the merchant (payee) and the cardholder (payer) to have a common EPN.

Without loss of generality, the EPN's marginal cost of servicing a card transaction is normalized to zero.[10] I assume for simplicity, and likewise Schwartz and Vincent (2006), that only linear pricing is feasible for the EPN. While in reality some EPNs may set membership fees (e.g. annual cardholder fees) there is no reason for them in this model given the assumption that there is a fixed mass of cardholders. The EPN solves the following maximization problem

$$\max_{m,r} \Pi_{EPN}\left(m,r\right) = \left(m-r\right) T\left(m,r\right)$$

where $T\left(m,r\right) \equiv \frac{\alpha}{\bar{b}_S} \int_{b_S^*}^{\bar{b}_S} q_e^*\left(b_S\right) db_S$ is the total volume of card transactions, and b_S^* denotes the card use benefit at which a merchant is indifferent between accepting cash and card payments, or only cash.

Summary and timing of the game. The participating agents interact according to the following sequential game. First, the EPN or the competent authority in case of an intervention aiming at maximizing social welfare sets whether merchants are either allowed to surcharge card payments, or not. Second, given the rule, the EPN sets the merchant fee, m, and the cardholder reward, r, per card payment. Third, merchants observe (m, r) and decide whether to accept card payments or not. Fourth, merchants accepting only cash define the price $p_c\left(b_S\right)$, while merchants accepting both cash and card payments define $p_c\left(b_S\right)$ and $p_e\left(b_S\right)$, respectively. Fifth, consumers without a payment card can only complete transactions with cash, while cardholders can choose between cash and card at card-accepting merchants. If a merchant chooses to accept only cash, all consumers regardless of holding a payment card may only purchase goods with cash at that merchant. A summary of the timing of the game follows in Table 1 below.

[10] The EPN may have to support a fixed cost, which must be sufficiently small such that, in equilibrium, profit is non-negative. Otherwise, the EPN would exit the market and no alternative to cash payments would be provided.

TABLE 1: The timing of the game

I.	The EPN or competent authority sets the payment system rule (surcharging or NSR)
II.	The EPN sets the merchant fee, m, and the cardholder reward, r, per card payment
III.	Merchants decide whether to join the EPN, or not
IV.	Merchants set prices for goods ($p_c(b_S)$ and $p_e(b_S)$ if it is a card-accepting merchant, or only $p_c(b_S)$ if it is a merchant that accepts only cash)
V.	Consumers decide which payment instrument to use at each merchant, conditional on the set of payment instruments accepted by each merchant

A summary of the model's notation is shown in Table 2 below.

TABLE 2: Notation

Exogenous variables	
α	Mass of cardholders
v	Maximal willingness to pay for a unit of a good
c	Marginal cost of producing a good
b_B	Cardholder benefit (network effect) of having an additional merchant accepting card payments
b_S	Merchant benefit of a card transaction relatively to cash
$\bar{b}_S$	Maximum value of b_S
Endogenous variables	
D	Mass of card-accepting merchants
q_e	Demand, per cardholder, for a good
q_c	Demand, per cash payer, for a good
p_e	Price of a unit of a good with card payment processed under the EPN
p_c	Price of a unit of a good when cash is used for payment
CS_c	Consumer surplus, per cash payer, for a good
CS_e	Consumer surplus, per cardholder paying with card, for a good
m	Merchant fee per card transaction processed under the EPN
r	Cardholder reward per card transaction processed under the EPN
T	Total number of card transactions processed under the EPN

3 The social optimum benchmark

This section sets out the first-best solution as benchmark. Hereafter, a variable with *opt* in superscript refers to the model in the first-best. Merchant fees and cardholder rewards may be construed as transfers from merchants to the EPN and from the EPN to cardholders, respectively. For that reason card fees and rewards are not relevant in the first-best analysis. In the first-best, merchants should join the EPN whenever the social benefit arising from card usage (e.g. cash-handling cost reduction, increased security in payments) exceeds the social cost of doing so, which is zero by assumption, i.e. $b_S \geq 0$. All cardholders should use their cards, and all merchants should accept card payments, i.e. $D^{opt} = 1$, because this is the most cost-efficient solution to make payments in the model. Also, the positive network effect on cardholders is maximized when all merchants accept card payments.

The output level for each good that achieves the maximum total surplus is such that the marginal social benefit equals the marginal social cost. Thus, the social optimal solution entails prices set at $p_c^{opt} = c$ and $p_e^{opt}(b_S) = c - b_S$ implying zero-profit for merchants.

The total surplus in the economy is then

$$TS^{opt} = \alpha \left(\int_0^{\bar{b}_S} \left(\int_{c-b_S}^{v} (v-x)\,dx \right) db_S + D^{opt} b_B \right) + (1-\alpha) \int_0^{\bar{b}_S} \left(\int_c^v (v-x)\,dx \right) db_S.$$

The EPN's market power to set merchant fees net of rewards (to cardholders) above cost, i.e. $m - r > 0$, is a market distortion that prevents the social optimum from being achieved in the absence of intervention. Similarly, merchants have an incentive and market power to charge retail prices above the respective marginal cost of the good. As will be shown further below, the NSR is unable to fully eliminate the negative effects of such market distortion on welfare, as also happens in Wright (2003), but can mitigate retail price inefficiency for cardholders.

4 Equilibrium with card payment surcharges

This section sets out the equilibrium when merchants are allowed to surcharge card payments. Hereafter, a variable with $*$ in superscript refers to the model with merchant surcharging. Given the demands (1) and (2) for a cash payer and a cardholder, respectively, a merchant with a card use benefit b_S sets

$$p_c^* = \frac{v+c}{2} \text{ and} \tag{4}$$

$$p_e^*(b_S) = \frac{v+c+m+r-b_S}{2}. \tag{5}$$

Merchants will accept payments with the EPN if and only if accepting cash and card is at least as profitable as accepting only cash. Only merchants with b_S sufficiently high will accept card payments, in particular $b_S \geq b_S^* \equiv m - r$. Thus, the mass of card-accepting merchants will be $D(m-r) = \int_{m-r}^{\bar{b}_S} \frac{1}{\bar{b}_S} db_S = 1 - \frac{m-r}{\bar{b}_S}$. The card surcharge at a card-accepting merchant, $p_e^*(b_S) - p_c^* = \frac{m+r-b_S}{2}$, is positive at least for merchants with a low card use benefit (around b_S^*). Card surcharges are decreasing in the card use benefit that merchants have, therefore, merchants with b_S sufficiently high may choose not to surcharge. This is consistent with the Australian experience where the Payments System Board required the removal of the NSR on credit cards from 2003 and credit card surcharge levels have varied across different merchants since then (Reserve Bank of Australia, 2011).

Given the prices in (4) and (5), the surplus of a consumer in a merchant is

$$CS_c^* = \frac{(v-c)^2}{8} \text{ if cash payment, or}$$

$$CS_e^* = \frac{(v-c+b_S-(m-r))^2}{8} \text{ if card payment.}$$

A cardholder chooses a card payment, rather than cash, if and only if $CS_c^* \leq CS_e^* \Leftrightarrow b_S \geq m-r$. Hence, at card-accepting merchants (i.e. those in the range $b_S^* \leq b_S \leq \bar{b}_S$), a cardholder chooses to pay with card, rather than cash. The total volume of card transactions is $T(m-r) = \frac{\alpha}{\bar{b}_S}\int_{m-r}^{\bar{b}_S} \frac{v-c-(m-r)+b_S}{2} db_S$, which is function of $m-r$, but not m or r separately. The EPN's problem can be written as

$$\max_{m-r\leq\bar{b}_S} \Pi_{EPN}(m-r) = (m-r)\,T(m-r)\,.$$

This leads to the well-known neutrality result set out in Proposition 1 below. Similar results are discussed for example in Gans and King (2003), and Schwartz and Vincent (2006).

Proposition 1 *In an equilibrium with merchant surcharging, the volume of card transactions, merchants' profits and the EPN's profit depend only on the EPN's margin $m-r$, and not on m and r individually. That is, if (m^*, r^*) maximizes the EPN's profit, then so does any pair (m', r') where $m'-r' = m^*-r^*$.*

Proposition 1 above is in line with the standard result that the effective incidence of a tax does not depend on whether it is formally placed on consumers or on merchants. This proposition is a general property of payment systems when merchants can surcharge (Gans and King, 2003). However, as will become clear in the next section, in the presence of the NSR, the EPN's profit depends on m and r individually. When merchants are allowed to surcharge card payments, the solution of the EPN's problem is

$$m^*-r^* = \frac{2}{3}\left(v-c+\bar{b}_S\right) - \frac{1}{3}\sqrt{4(v-c)^2+\bar{b}_S\left(2(v-c)+\bar{b}_S\right)}. \qquad (6)$$

It is noteworthy that $0 < m^*-r^* < \bar{b}_S$ ensuring a non-zero mass of card-accepting merchants, in particular $D^*(m^*-r^*) = 1 - \frac{\frac{2}{3}\left(v-c+\bar{b}_S\right)-\frac{1}{3}\sqrt{4(v-c)^2+\bar{b}_S\left(2(v-c)+\bar{b}_S\right)}}{\bar{b}_S}$.

5 Equilibrium under the NSR

Under the NSR each card-accepting merchant sets a single price regardless of the payment instrument chosen by the consumer. Hereafter, a variable with NSR in superscript refers to the model under the NSR. Merchants that accept only cash set $p_c^{NSR} = \frac{v+c}{2}$, while card-accepting merchants with a card use benefit b_S set a uniform price at $p_e^{NSR}(b_S) = \frac{v+c+\alpha(m+r-b_S)}{2}$. Only merchants with b_S sufficiently high will accept card payments, in particular

$$b_S \geq b_S^{NSR}(m,r) \equiv \frac{\sqrt{(v-c)^2 + 4(1-\alpha) r (v-c+r)} - (v-c+2r-\alpha(m+r))}{\alpha}. \quad (7)$$

Proposition 2 *Fix m and r at any given positive level. Compared to the case where merchants are allowed to surcharge, the mass of card-accepting merchants is lower under the NSR.*

Proposition 2 can be shown by comparing the expression $b_S^{NSR}(m,r)$ in (7) against $b_S^*(m,r) \equiv m-r$, which results in $b_S^{NSR}(m,r) > b_S^*(m,r)$, and consequently $D^{NSR}(m,r) < D^*(m,r)$. Under the NSR the mass of card-accepting merchants is $D^{NSR}(m,r) = 1 - b_S^{NSR}(m,r)/\bar{b}_S$. Card-accepting merchants are worse off under the NSR through being constrained in the ability to price discriminate. This and the results further below hold qualitatively regardless of the scale of card-accepting merchants and the proportion of cardholders in the economy. Some merchants choosing to accept card payments when allowed to surcharge choose *not* to do so under the NSR. When merchants are allowed to surcharge, and thus price discriminate per payment method, they have a greater incentive to accept card payments because they gain a second price instrument allowing them to capture further value from consumers. This result may help to explain why the share of merchants surcharging credit cards has grown significantly after the NSR ban in Australia.

The EPN's problem is

$$\max_{m,r} \Pi_{EPN}^{NSR}(m,r) = (m-r) T^{NSR}(m,r) \text{ subject to}$$

$$T^{NSR}(m,r) = \frac{\alpha}{\bar{b}_S} \int_{b_S^{NSR}(m,r)}^{\bar{b}_S} \left(\frac{v-c-\alpha(m+r-b_S)}{2} + r \right) db_S,$$

$$b_S^{NSR}(m,r) \leq \bar{b}_S.$$

The optimal solution for the EPN's problem entails

$$\begin{cases} m^{NSR} = \frac{v-c}{3} + \frac{5\bar{b}_S}{6} - \frac{\sqrt{4(v-c)^2 + \bar{b}_S\left(2(v-c)+\bar{b}_S\right)}}{6} \\ r^{NSR} = -\frac{v-c}{3} + \frac{\bar{b}_S}{6} + \frac{\sqrt{4(v-c)^2 + \bar{b}_S\left(2(v-c)+\bar{b}_S\right)}}{6} \end{cases}, \quad (8)$$

where $m^{NSR} + r^{NSR} = \bar{b}_S$, $m^{NSR} - r^{NSR} = m^* - r^*$, and $m^* - r^*$ is defined in (6). The EPN's profit margin is the same regardless of the NSR. This is because neither (i) the degree of competition in the provision of electronic payment services, nor (ii) the size of the group of cardholders was affected by the NSR. On (i), Economides (2009) suggested that with multiple EPNs the NSR may serve the purpose of increasing the profit margin to collusive levels among the EPNs. However, the assumption of a monopolist EPN in my model rules out such potential anti-competitive effects brought about by the NSR. To the extent that such an assumption is a good approximation to a number of countries (Cabral, 2006), the magnitude of the impact of the NSR on the EPN's profit margin will be relatively limited. On (ii), the assumption of a fixed mass α of cardholders does not capture potential variations in the size of this group when the NSR is in force. Nevertheless, Kinsey (1981) and Amendola, Pellecchia and Sensini (2016) found that consumers' decisions to subscribe to a credit card can be broadly explained by reasons that are independent of the NSR, such as: income, place of residence, use of checking and savings accounts, attitude towards credit, age and occupation. Even considering elastic card adoption in the model, it is unclear how the mass of cardholders would vary by virtue of the NSR. On the one hand, under the NSR, consumers are better off paying with card compared to cash because cardholders receive rewards for the same retail price, which incentivizes card adoption. On the other hand, the mass of card-accepting merchants is lower under the NSR (Proposition 2) discouraging consumers to adopt payment cards.

Proposition 3 *Compared to when surcharging is allowed, if the NSR is imposed, then: (i) for merchants that accept card payments under the NSR, the volume of cash transactions will fall and the volume of card transactions will rise, while the total volume of transactions will remain unchanged; (ii) for merchants that accept card payments only when surcharging is allowed, the total volume of transactions will fall; and (iii) the total volume of transactions in the economy as a whole will fall.*

When surcharging is permitted, cash payers face lower retail prices than cardholders at card-accepting merchants, i.e. $p_c^* = \frac{v+c}{2} \leq \frac{v+c+\left(\bar{b}_S - b_S\right)}{2} = p_e^*\left(b_S\right)$. The NSR imposes a single price constraint on retail prices paid by cash payers and cardholders at card-accepting merchants. Such constraint induces card-accepting merchants to set the level of that single price at $p_e^{NSR}\left(b_S\right) = \frac{v+c+\alpha\left(\bar{b}_S - b_S\right)}{2}$, where $p_c^* \leq p_e^{NSR}\left(b_S\right) \leq p_e^*\left(b_S\right)$ since $0 < \alpha < 1$ and $b_S \in \left[0, \bar{b}_S\right]$ by assumption.[11] Compared to when surcharging is permitted, under the NSR cash payers pay more and cardholders pay less at card-accepting merchants. Hence, the NSR results in falling volumes of cash transactions and rising volumes of card transactions at card-accepting merchants. This is consistent with surveys suggesting that surcharging has steered consumers away from using credit cards towards cash in Australia (Reserve Bank of Australia, 2011). In general, the net impact of the NSR on the total volume of transactions per card-accepting merchant is unclear. However, in this model the total volume of transactions per card-accepting merchant remains unchanged because of the linearity of demands.

Proposition 2 points out that there are fewer card-accepting merchants under the NSR. This is because some merchants *only* accept card payments if allowed to surcharge. Should surcharging be allowed, a cardholder buys a quantity $q_e^*\left(b_S\right) = \frac{v-c-(m^*-r^*)+b_S}{2}$ per card-accepting merchant, while a cash payer purchases $q_c^* = \frac{v-c}{2} \leq q_e^*\left(b_S\right)$, since $b_S \geq m^* - r^*$. If the NSR is in

[11] The assumption $\bar{b}_S \leq v - c$ ensures that the group of cash payers will be served when the NSR is in force. Under this condition, $p_e^{NSR}\left(b_S\right)$ is lower than cash payers' maximal willingness to pay for a unit of a good, v.

force, at merchants that accept card payments only when allowed to surcharge, cardholders have no option but to pay cash and thus choose to buy fewer units of the good (than if they could pay by card and receive rewards), while cash payers face the same retail price and buy the same quantity regardless of the NSR implementation.

In a nutshell, if the NSR is implemented, the total volume of transactions will: (i) decrease for merchants in the range $b_S \in \left[b_S^*, b_S^{NSR}\right)$ (i.e. those that only accept card payments when allowed to surcharge); and (ii) remain unchanged for merchants in the ranges $b_S \in \left[b_S^{NSR}, \bar{b}_S\right]$ (i.e. those that always accept card payments irrespective of the NSR) and $b_S \in [0, b_S^*)$ (i.e. those that never accept card payments irrespective of the NSR). Therefore, the total volume of transactions in the economy as a whole will fall with the NSR implementation.

6 Welfare analysis and efficiency

In this section, I investigate the NSR effect on social welfare and economic efficiency in the absence and presence of network effects.

Proposition 4 *In the absence of network effects, i.e.* $b_B = 0$*, and compared to the equilibrium where merchants are allowed to surcharge, under the NSR: (i) the EPN's profit margin per card transaction* $(m - r)$ *and profit level remain unchanged; (ii) cash payers make fewer transactions and the respective consumer surplus falls; (iii) cardholders make more transactions and the respective consumer surplus rises; and (iv) merchants' profits fall.*

Under the NSR, the merchant fee and cardholder reward $\left(m^{NSR}, r^{NSR}\right)$ are determined in (8). In the model, the EPN's profit margin $m^{NSR} - r^{NSR}$ is the same as under surcharging. Proposition 3 states that the volume of card transactions per card-accepting merchant rises as a result of the NSR. However, fewer merchants will accept card payments under the NSR (Proposition 2). These two effects offset each other resulting in an unchanged total volume of card transactions in the economy as a whole. Given that neither the EPN's profit margin, nor the total volume of card transactions is altered with the NSR, the EPN's profit is invariant to the NSR. Note though that this relies on the assumptions that (i) the EPN is a monopolist, and (ii) the size of the group of cardholders is unaffected by the NSR. Allowing for competition at the EPN level and (or) an expansion in the group of cardholders, the EPN's profit would potentially increase with the NSR.

Under the NSR, cash payers will make fewer transactions at card-accepting merchants. This is because card-accepting merchants mark up retail prices for all consumers resulting in cardholders being "subsidized" by cash payers.[12]

[12] The welfare transfers from cash payers to cardholders have been researched both theoretically and empirically, e.g. Gans and King (2003), Schwartz and Vincent (2006), and Schuh, Shy and Stavins (2010).

Merchant fees are passed on to all consumers in the form of higher retail prices irrespective of the payment instrument. Thus, under the NSR, cash payers face higher retail prices to cover merchant fees associated with card payments. Given that the EPN uses merchant fees to finance rewards to cardholders, and cash payers do not receive rewards, cash payers also finance part of the cardholder rewards. As a result, cash payers' consumer surplus is lower under the NSR.

Despite the fact that fewer merchants accept card payments under the NSR (Proposition 2), cardholders make the same volume of card transactions. Cardholders concentrate the volume of card transactions in a smaller group of merchants (i.e. the card-accepting merchants under the NSR) increasing the volume of card transactions per card-accepting merchant. Additionally, given that under the NSR more merchants accept only cash, cardholders make more cash transactions (keeping fixed the volume of cash transactions per merchant, as compared to the surcharge equilibrium). In a nutshell, under the NSR, cardholders complete the same total volume of card transactions but make more cash transactions, as compared to the surcharge equilibrium.

The NSR imposes two welfare effects on cardholders. On the one hand, the "subsidy" effect from cash payers increases their surplus. On the other hand, the reduction in merchant acceptance of card payments decreases cardholders' surplus. In the absence of network effects, the "subsidy" effect dominates the "merchant acceptance" effect. This is because in the model the total volume of transactions per cardholder increases with the NSR and as a result cardholders are better off.

The group of card-accepting merchants is clearly worse off through being constrained in their ability to price discriminate consumers depending on the payment instrument. The merchants with a sufficiently low card use benefit, i.e. those in the range $b_S \in [0, b_S^*)$ that will choose to accept only cash regardless of the NSR, are indifferent to the NSR.

In a nutshell, the NSR generates opposite welfare variations on different groups of agents. To better understand the impacts of the NSR, I discuss below two aspects of economic efficiency: retail price efficiency for cardholders, and (in)efficiency in merchant acceptance of payment cards in the presence of network effects.

6.1 NSR and retail price efficiency for cardholders

In general, monopolists do not efficiently price goods. The negative slope of the demand for goods means that the price charged by a monopolist merchant is above the marginal revenue. As profit-maximizing merchants equate marginal revenue with marginal cost, the price is set above marginal cost. Proposition 3 (i) suggests that for card-accepting merchants the implementation of the NSR results in a rising volume of card transactions and a falling volume of cash transactions, while the total volume of transactions remains unchanged. This is because $p_c^* \leq p_e^{NSR}(b_S) \leq p_e^*(b_S)$ and thus, under the NSR, cardholders pay a lower price (closer to marginal cost) which improves retail price efficiency for goods sold to cardholders. The NSR is mitigating a problem of double-marginalization of card payments.

A relevant aspect in the model is that converting payments from cash to card generates cost savings for merchants. Thus, the NSR can improve payment efficiency by shifting output from cash payers to cardholders. Also, it is noteworthy that in this model the total volume of card transactions in the economy as a whole is the same regardless of the NSR. However, under the NSR, card transactions are completed with merchants in the range of $b_S \in \left[b_S^{NSR}, \bar{b}_S\right]$, rather than $b_S \in \left[b_S^{*}, \bar{b}_S\right]$ when surcharging is feasible, where $b_S^{NSR} > b_S^{*}$ (Proposition 2). Implementing the NSR shifts card transactions towards more cost-effective merchants (with higher b_S) enhancing social welfare.

For example, consider the case where $\left(v, c, \alpha, \bar{b}_S, b_B\right) = (100, 50, 0.75, 5, 0)$, i.e. consumers' maximal willingness to pay for the good itself is normalized to 100, the marginal cost is half of v (allowing for 25% profit margin to a merchant that only accepts cash), 75% of consumers are cardholders (US case for credit cards), the merchants' maximal card use benefit is 5% of v (equivalent to 10% reduction in the marginal cost), and there are no network effects. For the parameter values above, the EPN sets $(m^*, r^*) = \left(m^{NSR}, r^{NSR}\right) = (3.7, 1.3)$. Taking as reference the price of a merchant that only accepts cash, the EPN prices mean a merchant fee of c. 5% and cardholder rewards of c. 1.7%. The total surplus in the economy would increase by more than 0.5% with the NSR compared to the surcharge equilibrium. This result holds qualitatively for a number of other sets of parameters that exclude network effects.

6.2 NSR, network effects and (in)efficiency in merchant acceptance

Efficiency in merchant acceptance of payment cards involves minimizing the costs of supplying a good. In this model, the costs associated with a card transaction are lower compared to cash. From the social perspective, it is cost-effective that all merchants accept card payments, i.e. $D^{opt} = 1$ (Section 3). Moreover, due to security concerns and (or) cardholders' opportunity cost regarding the time required to withdraw cash from banks, cardholders care about the network size of card-accepting merchants where they can use their cards. This network effect of merchants on cardholders can be taken into account by setting $b_B > 0$.

If b_B is sufficiently high, with the exception of the EPN, all agents (cash payers, cardholders and merchants) are worse off with the NSR implementation. The reasons why cash payers and merchants are worse off, and cardholders better off with the NSR implementation were already discussed above (after Proposition 4) for the case where there are no network effects. However, cardholders may strongly prefer an EPN with larger merchant acceptance. Given that fewer merchants accept card payments under the NSR, a sufficiently strong preference for not carrying cash (i.e. a sufficiently strong network effect) implies that cardholders will be also worse off under the NSR as compared to the surcharge equilibrium. In a nutshell, implementing the NSR in the presence of sufficiently strong network effects makes cash payers, cardholders and merchants all worse off, the EPN is indifferent (Proposition 4), while the total surplus in the economy decreases.

7 Conclusions

This paper sets out a three-party model with consumers (cash payers and cardholders), merchants (local monopolists) and an EPN to assess the efficiency and welfare effects of the NSR for card payments. I consider in this model: (i) merchant heterogeneity with respect to card use benefits, (ii) positive network effects of merchants on cardholders and (iii) endogenous transaction volumes. The contribution of this paper is three-fold.

First, it provides an argument for the implementation of the NSR based on economic efficiency. Compared to the surcharge equilibrium, card transactions have a lower retail price under the NSR, which improves retail price efficiency for cardholders. A relevant aspect in the model is that converting payments from cash to card generates cost savings for merchants. Thus, the NSR can improve payment efficiency and promote social welfare by shifting output from cash payers to cardholders. This suggests that the NSR may contribute to the goal of some policymakers to decrease cash usage, e.g. to mitigate tax evasion.

Second, it discusses the welfare variations introduced by the NSR in the presence of network effects. If network effects are sufficiently strong, with the exception of the EPN, all groups of agents (cash payers, cardholders and merchants), and society as a whole, are worse off with the NSR implementation. This is because fewer merchants accept card payments under the NSR, and the network size of card-accepting merchants matters to cardholders. This suggests that network effects play a relevant role in whether the NSR is socially desirable.

Third, it suggests that the social optimal policy on the NSR may differ from market to market (see also Economides and Henriques, 2011). In competitive markets, allowing for card surcharges can be socially preferable to the NSR to incentivise competition at the EPN level. However, in markets where merchants have significant market power, the NSR mitigates the double-marginalization of card payments and improves payment efficiency. This latter effect contributes to the view that in non-competitive markets the NSR is socially preferable rather than to allow card payment surcharges.

8 Appendix

Proof of Proposition 1 The EPN's problem is

$$\begin{aligned}
\max_{m,r} \Pi_{EPN}(m,r) &= (m-r)\,T(m,r) \text{ subject to} \\
T(m,r) &= \frac{\alpha}{\bar{b}_S}\int_{m-r}^{\bar{b}_S} \frac{v-c-(m-r)+b_S}{2}\,db_S \\
\bar{b}_S &\geq m-r.
\end{aligned}$$

Replacing $m - r \equiv X$, the EPN's problem can be re-written as a single-variable maximization problem

$$\max_{X \leq \bar{b}_S} \Pi_{EPN}(X) = \frac{\alpha X}{2\bar{b}_S}\left((v-c-X)\left(\bar{b}_S - X\right) + \frac{\bar{b}_S^2}{2} - \frac{X^2}{2}\right).$$

Let X^* denote the solution for the EPN's problem above. If $m^* - r^* = X^*$ and $m' - r' = m^* - r^*$, then it follows that $m' - r' = X^*$. □

Proof of Proposition 2 This proof consists in showing that $D^{NSR}(m,r) < D^*(m,r)$, where $D^{NSR}(m,r) \equiv 1 - \frac{b_S^{NSR}(m,r)}{\bar{b}_S}$ and $D^*(m,r) \equiv 1 - \frac{b_S^*(m,r)}{\bar{b}_S}$. Thus, $D^{NSR}(m,r) < D^*(m,r) \Leftrightarrow b_S^{NSR}(m,r) > b_S^*(m,r)$, where $b_S^{NSR}(m,r) \equiv \frac{\sqrt{(v-c)^2 + 4(1-\alpha)r(v-c+r)} - (v-c+2r-\alpha(m+r))}{\alpha}$ and $b_S^*(m,r) \equiv m - r$. It can be shown that $b_S^{NSR}(m,r) > b_S^*(m,r)$ since

$$\frac{1}{\alpha}\left(\sqrt{(v-c)^2 + 4(1-\alpha)r(v-c+r)} - (v-c+2r-\alpha(m+r))\right) > m - r \Leftrightarrow$$

$$\sqrt{(v-c)^2 + 4(1-\alpha)r(v-c+r)} > v - c + 2r(1-\alpha) \Leftrightarrow 4\alpha(1-\alpha)r^2 > 0,$$

given that $0 < \alpha < 1$ and $r > 0$ by assumption. □

Proof of Proposition 3 (i) Merchants with card use benefits in the range $\left[b_S^{NSR}, \bar{b}_S\right]$ accept card payments under the NSR. The volume of cash transactions, per merchant, in the range $\left[b_S^{NSR}, \bar{b}_S\right]$ is: $(1-\alpha)q_c^* = (1-\alpha)\frac{v-c}{2}$ under surcharging, and $(1-\alpha)q_c^{NSR} = (1-\alpha)\frac{v-c-\alpha\left(\bar{b}_S - b_S\right)}{2}$ under the NSR. It is straightforward that $(1-\alpha)q_c^* \geq (1-\alpha)q_c^{NSR}$ given that $0 \leq b_S \leq \bar{b}_S$.

The total volume of transactions, per merchant, in the range $\left[b_S^{NSR}, \bar{b}_S\right]$ is $Q^*(b_S) \equiv \alpha q_e^* + (1-\alpha)q_c^* = \frac{v-c-\alpha(m^* - r^* - b_S)}{2}$ under surcharging, and $Q^{NSR}(b_S) \equiv \alpha q_e^{NSR} + (1-\alpha)q_c^{NSR} = \frac{v-c-\alpha\left(m^{NSR} - r^{NSR} - b_S\right)}{2}$ under the NSR. Given that $m^* - r^* = m^{NSR} - r^{NSR}$, therefore $Q^*(b_S) = Q^{NSR}(b_S)$, and consequently $\alpha q_e^* \leq \alpha q_e^{NSR}$ because $(1-\alpha)q_c^* \geq (1-\alpha)q_c^{NSR}$.

(ii) Merchants with transactional benefits in the range $\left[b_S^*, b_S^{NSR}\right)$ will accept card payments if surcharging is allowed, otherwise, under the NSR, these merchant will accept only cash. The total volume of transactions, per merchant, in the range $\left[b_S^*, b_S^{NSR}\right)$, is

$$Q^*(b_S) = \frac{v-c-\alpha(m^* - r^* - b_S)}{2} \text{ under surcharging, and}$$

$$Q^{NSR} = \frac{v-c}{2}, \text{ under the NSR.}$$

Using the fact that $m^* - r^* = b_S^*$ and $b_S \geq b_S^*$, thus $Q^*(b_S) \geq Q^{NSR}$.

(iii) The total volume of transactions remains unchanged for merchants in the range $[0, b_S^*)$ as these merchants always choose to accept only cash irrespective of the NSR. If the NSR is implemented, the total volume of transactions will remain unchanged for merchants in the range $\left[b_S^{NSR}, \bar{b}_S\right]$ as shown in (i), while the total volume of transactions will fall for merchants in the range $\left[b_S^*, b_S^{NSR}\right)$ as shown in (ii). Thus, for the economy as a whole, the total volume of transactions decreases with the NSR implementation. □

Proof of Proposition 4 (i) The solution of the EPN's problem, when merchants are allowed to surcharge, is given by

$$m^* - r^* = \frac{2}{3}\left(v - c + \bar{b}_S\right) - \frac{1}{3}\sqrt{4\left(v-c\right)^2 + \bar{b}_S\left(2\left(v-c\right) + \bar{b}_S\right)}.$$

The solution of the EPN's problem, when merchants are under the NSR, is given by

$$\begin{cases} m^{NSR} = \frac{1}{3}\left(v-c\right) + \frac{5}{6}\bar{b}_S - \frac{1}{6}\sqrt{\bar{b}_S\left(2\left(v-c\right)+\bar{b}_S\right) + 4\left(v-c\right)^2} \\ r^{NSR} = -\frac{1}{3}\left(v-c\right) + \frac{1}{6}\bar{b}_S + \frac{1}{6}\sqrt{\bar{b}_S\left(2\left(v-c\right)+\bar{b}_S\right) + 4\left(v-c\right)^2} \end{cases},$$

thus $m^{NSR} - r^{NSR} = m^* - r^*$.

When merchants are allowed to surcharge, the volume of card transactions is given by

$$T^*\left(m^*, r^*\right) = \frac{\alpha}{\bar{b}_S}\int_{m^*-r^*}^{\bar{b}_S} \frac{v - c - \left(m^* - r^*\right) + b_S}{2} db_S,$$

while under the NSR, the volume of card transactions is

$$T^{NSR}\left(m^{NSR}, r^{NSR}\right) = \frac{\alpha}{\bar{b}_S}\int_{b_S^{NSR}\left(m^{NSR}, r^{NSR}\right)}^{\bar{b}_S} \left(\frac{v - c - \alpha\left(m^{NSR} + r^{NSR} - b_S\right)}{2} + r^{NSR}\right) db_S,$$

where $b_S^{NSR}\left(m^{NSR}, r^{NSR}\right)$ is defined in (7). Given that $m^{NSR} - r^{NSR} = m^* - r^*$ and $T^*\left(m^*, r^*\right)$ depends on $m^* - r^*$, rather than on m^* and r^* individually, thus $T^*\left(m^*, r^*\right) = T^*\left(m^{NSR}, r^{NSR}\right)$. Assuming without loss of generality that $m^* = m^{NSR} = m$ and $r^* = r^{NSR} = r$,

$$T^*\left(m, r\right) - T^{NSR}\left(m, r\right) = \frac{\alpha\left(1-\alpha\right)\left(\bar{b}_S - \left(m + r\right)\right)^2}{4\bar{b}_S} = 0,$$

given that, in equilibrium, $m + r = m^{NSR} + r^{NSR} = \bar{b}_S$. Thus, the EPN's profit is the same irrespective of the NSR.

(ii) If merchants are allowed to surcharge, a cash payer will buy $q_c^* = \frac{v-c}{2}$ from each and every merchant. Under the NSR, a cash payer buys $q_c^* = \frac{v-c}{2}$ from each merchant that accepts only cash, while buying $q_c^{NSR}\left(b_S\right) = \frac{v-c-\alpha\left(\bar{b}_S - b_S\right)}{2}$ from each card-accepting merchant. Thus, the aggregate volume of transactions made by a cash payer must be lower under the NSR, given that $b_S \leq \bar{b}_S$ by assumption.

If merchants are allowed to surcharge, the consumer surplus of a cash user is $\left(v-c\right)^2/8$ at each and every merchant. Under the NSR, the consumer surplus of a cash user is $\left(v-c\right)^2/8$ at merchants accepting only cash, and $\left(v - c - \alpha\left(\bar{b}_S - b_S\right)\right)^2/8$ at card-accepting merchants. Thus, the consumer surplus of a cash payer must be lower under the NSR, given that $b_S \leq \bar{b}_S$ by assumption.

(iii) If merchants are allowed to surcharge, the total volume of transactions per cardholder is

$$\frac{v-c}{2}\frac{m^*-r^*}{\bar{b}_S}+\frac{1}{\bar{b}_S}\int_{m^*-r^*}^{\bar{b}_S}\frac{v-c+r-m+b_S}{2}db_S, \tag{9}$$

and the consumer surplus generated by such volume of transactions is

$$\frac{(v-c)^2}{8}\frac{m^*-r^*}{\bar{b}_S}+\frac{1}{\bar{b}_S}\int_{m^*-r^*}^{\bar{b}_S}\frac{1}{2}\left(\frac{v-c-(m-r)+b_S}{2}\right)^2 db_S. \tag{10}$$

Under the NSR, the total volume of transactions per cardholder is

$$\frac{v-c}{2}\frac{b_S^{NSR}\left(m^{NSR},r^{NSR}\right)}{\bar{b}_S}+\frac{1}{\bar{b}_S}\int_{b_S^{NSR}(m^{NSR},r^{NSR})}^{\bar{b}_S}\left(\frac{v-c-\alpha\left(\bar{b}_S-b_S\right)}{2}+r^{NSR}\right)db_S, \tag{11}$$

and the consumer surplus generated by such volume of transactions is

$$\frac{(v-c)^2}{8}\frac{b_S^{NSR}\left(m^{NSR},r^{NSR}\right)}{\bar{b}_S}+\frac{1}{\bar{b}_S}\int_{b_S^{NSR}(m^{NSR},r^{NSR})}^{\bar{b}_S}\frac{1}{2}\left(\frac{v-c-\alpha\left(\bar{b}_S-b_S\right)}{2}+r^{NSR}\right)^2 db_S, \tag{12}$$

where $b_S^{NSR}\left(m^{NSR},r^{NSR}\right)$ is defined in (7).

The expression in (9) is smaller than the one in (11). Using the fact that $m^{NSR}+r^{NSR}=\bar{b}_S$, the difference between (11) and (9) can be written as

$$(v-c)\frac{\sqrt{4r(1-\alpha)(v-c+r)+(v-c)^2}-2r(1-\alpha)-(v-c)}{2\alpha\bar{b}_S}>0 \Leftrightarrow 4\alpha(1-\alpha)r^2>0. \tag{13}$$

The expression in (10) is smaller than the one in (12). Using the fact that $m^{NSR}+r^{NSR}=\bar{b}_S$, the difference between (12) and (10), denoted by ΔTCS_e below, can be written as

$$\Delta TCS_e=\frac{\left(\begin{array}{c}(12(v-c)+8r)(1-\alpha)r^2-2(v-c)^3\\ +\left(2(v-c)^2-4r(1-\alpha)(v-c+r)\right)\sqrt{4r(1-\alpha)(v-c+r)+(v-c)^2}\end{array}\right)}{24\alpha\bar{b}_S}. \tag{14}$$

Applying algebraic manipulation and the first inequality in (13) to ΔTCS_e it can be concluded that $\Delta TCS_e>0$.

(iv) Merchants with transactional benefits in the range $[0,b_S^*)$ only accept cash irrespective of the NSR implementation. Thus, the profit for these merchants is the same regardless of the NSR.

Merchants with transactional benefits in the range $\left[b_S^*,b_S^{NSR}\right)$ will accept card payments, if surcharging is allowed; otherwise, under the NSR, the merchant will accept only cash. For merchants with b_S in that range, the profit is

$$\Pi\left(b_S\right)=\begin{cases}\frac{1}{4}\left(v-c\right)^2 \text{ if NSR} \\ \alpha\left(\frac{v-c+b_S-(m^*-r^*)}{2}\right)^2+\left(1-\alpha\right)\left(\frac{v-c}{2}\right)^2 \text{ if surcharging allowed}\end{cases}.$$

It can be shown that $\alpha\left(\frac{v-c+b_S-(m^*-r^*)}{2}\right)^2+\left(1-\alpha\right)\left(\frac{v-c}{2}\right)^2>\frac{1}{4}\left(v-c\right)^2$, because $\frac{v-c+b_S-(m^*-r^*)}{2}>\frac{v-c}{2}\Leftrightarrow b_S>b_S^*\equiv m^*-r^*$. Hence, merchants with $b_S\in\left[b_S^*,b_S^{NSR}\right)$ are worse off with the NSR implementation.

Merchants with card use benefits in the range $\left[b_S^{NSR},\bar{b}_S\right]$ accept card payments regardless of the NSR implementation. Within that range, a merchant's profit is

$$\begin{aligned}\Pi^{NSR}\left(b_S\right) &= \alpha\left(\frac{v-c+\alpha\left(\bar{b}_S-b_S\right)}{2}+b_S-m^{NSR}\right)\left(\frac{v-c-\alpha\left(\bar{b}_S-b_S\right)}{2}+r^{NSR}\right) \\ &\quad+\left(1-\alpha\right)\left(\frac{v-c+\alpha\left(\bar{b}_S-b_S\right)}{2}\right)\left(\frac{v-c-\alpha\left(\bar{b}_S-b_S\right)}{2}\right)\end{aligned}$$

if NSR is in place, and

$$\Pi^*\left(b_S\right)=\alpha\left(\frac{v-c+b_S-\left(m^*-r^*\right)}{2}\right)^2+\left(1-\alpha\right)\left(\frac{v-c}{2}\right)^2$$

if merchant surcharging is allowed. It can be shown that $\Pi^{NSR}\left(b_S\right)\leq\Pi^*\left(b_S\right)$ for $b_S\in\left[b_S^{NSR},\bar{b}_S\right]$. Using the fact that $m^{NSR}+r^{NSR}=\bar{b}_S$,

$$\Pi^{NSR}\left(b_S\right)-\Pi^*\left(b_S\right)=-\frac{1}{4}\alpha\left(1-\alpha\right)\left(\bar{b}_S-b_S\right)^2\leq 0.$$

Hence, merchants with card use benefits in the range $\left[b_S^{NSR},\bar{b}_S\right]$ are worse off with the NSR implementation. □

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