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Working Paper

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Working Paper, No. 345

Provided in Cooperation with:

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Suggested Citation: Ewerhart, Christian; Li, Sheng (2023) : Imposing choice on the uninformed: The case of dynamic currency conversion, Working Paper, No. 345, University of Zurich, Department of Economics, Zurich, <https://doi.org/10.5167/uzh-187399>

This Version is available at:

<https://hdl.handle.net/10419/268477>

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**University of
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University of Zurich
Department of Economics

Working Paper Series

ISSN 1664-7041 (print)
ISSN 1664-705X (online)

Working Paper No. 345

Imposing Choice on the Uninformed: The Case of Dynamic Currency Conversion

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First version: April 2020
This version: January 2023

Imposing Choice on the Uninformed: The Case of Dynamic Currency Conversion*

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Abstract. It is a common experience for present-day consumers making an international payment via credit or debit card to be invited to choose the currency in which they wish to have the transaction executed. While this choice, made feasible by a technology known as *dynamic currency conversion (DCC)*, seems to foster competition, we argue that the opposite is the case. In fact, the unique pure-strategy equilibrium in a natural fee-setting game, with uninformed and possibly inattentive consumers, turns out to be highly asymmetric, entailing fees for the service provider that persistently exceed the monopoly level. Although losses in welfare may be substantial, a regulatory solution is unlikely to come about due to a global free-rider problem.

Keywords. Dynamic currency conversion · Payment cards · Price competition · Monopoly · Free-rider problem · Rational inattention

JEL-Codes. D21 – Firm Behavior: Theory; G21 – Banks, Depository Institutions, Micro Finance Institutions, Mortgages; G28 – Government Policy and Regulation; G53 – Financial Literacy

*) First version: April 30, 2020; this version: January 4, 2023. Two anonymous referees provided helpful suggestions on an earlier version. For useful discussions and comments, we would like to thank Sarah Auster, Özlem Bedre-Defolie, Pavlo Blavatsky, Robert Edwards (discussant), Ege-men Eren, Renato Gomes, Elisabetta Iossa, Johannes Johnen, Dan Kovenock, Mathias Kruttli, Ye Li, David Myatt, Jean-Charles Rochet, Nicolas Schutz, Attila Tasnádi, Jidong Zhou, as well as participants at the UZH Banking Workshop, the Oligo Workshop 2020, and the Econometric Society European Meeting 2021. Sheng Li thanks Emory University for its hospitality and acknowledges funding from the Swiss National Science Foundation (grant No. P1ZH P1_191535).

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1. Introduction

For about two decades by now, it has been common practice in international payment that users of a credit or debit card are invited to choose the currency in which they wish their transaction to be executed.¹ Typically, the merchant (the ATM operator, the online shop) presents the choice in the form of a simple question such as the following:

“In which currency do you wish to pay:

(H) In your home currency (the currency of your payment card), or

(F) in foreign/local currency?”

Subsequent to answering this question, the transaction may be authorized to be executed in the selected currency. The technology allowing for this possibility, known as *dynamic currency conversion (DCC)*, relies on a protocol whereby the total in foreign currency is automatically converted to the card-holder’s home currency. Proponents of DCC have pointed to the fact that consumers might feel more comfortable using their home currency, e.g., because the uncertainty regarding the exchange rate in the moment of payment is eliminated. Moreover, the principles of economic theory suggest that offering an additional alternative cannot be to the detriment of a rational decision maker.

In contrast to such reasoning, however, consumer organizations in numerous jurisdictions have long insisted on their position that DCC is almost never beneficial

¹For example, a U.S. citizen on vacation in Mexico may pay a hotel bill either in USD or in Mexican pesos. Similarly, a business traveler from the United Kingdom withdrawing cash from an ATM in Reykjavik may be charged either in GBP or in Icelandic krona. Or else, an individual living and working in Switzerland may pay at the checkout of a German online shop either in Swiss francs or in euros.

to the card-holder. Indeed, this suspicion has found unequivocal validation through a large variety of case studies.² To understand these seemingly contradictory positions, it is helpful to review the settlement process customary in international electronic retail payments. And indeed, DCC documentation manuals reveal that, in cases where the home currency option is chosen, the currency conversion is not carried out by the bank that issued the payment card, but instead by a third party known as the DCC service provider. In other words, an equivalent way for the merchant etc. to ask the question above would be:

“Who should carry out the currency conversion for you:

(H’) Your bank’s payment network (as shown on your card), or

(F’) a foreign/local DCC service provider?”

Perplexing is now the fact that, according to the hard-coded implementation of DCC, option (H) in the first choice problem corresponds to option (F’) in the second choice problem, while option (F) corresponds to option (H’).³ Thus, the *framing* of the choice problem has the potential to twist the consumer’s perception of the focal option (choosing the home currency corresponds to choosing a service by a foreign firm that the consumer usually has no relation with), rendering the underlying logic potentially impenetrable for quite a few.⁴

²The evidence will be surveyed in the next section.

³For instance, the U.S. citizen choosing payment in USD would have the currency conversion carried out by the local service provider, whereas the same individual choosing payment in Mexican pesos would have the currency conversion carried out by the payment network of the U.S. bank that issued the credit card.

⁴We use the term “framing” here even though it is usually interpreted in a slightly different way. Tversky and Kahneman (1981) observed preference reversal in objectively identical choice problems with different semantics, such as emphasizing the percentage of patients that deceased in a treatment versus the percentage of patients that survived. In our example, the framing goes somewhat further in that it creates an objectively different choice problem for the uninformed

In this paper, we study the economic mechanisms underlying DCC using tools from theoretical industrial organization and beyond. Considered is a model of price competition between a finite number of card-issuing firms and a single DCC service provider.⁵ As in a standard Bertrand setting, consumers know which fee is charged by which card-issuing firm. Consumers are likewise informed about the potentially very high fee that is charged by the DCC service provider.⁶ In contrast to the standard setting, however, we will give the merchant the option to frame the consumer's choice as described above. Clearly, if the consumer is perfectly informed about the technological details of the DCC implementation, i.e., if the consumer knows the *true* state of the world, then such framing cannot affect the outcome of rational choice.

However, if the (possibly inattentive) consumer does not know how the choice of the payment currency translates into which entity is carrying out the currency conversion, then the framing of the consumer's decision may make a difference. To model this possibility, we introduce a *counterfactual* state of the world in which the respective roles of the issuer and the service provider are just swapped. I.e., in the counterfactual state, (H) corresponds to (H') while (F) corresponds to (F'). With incomplete information about the state of the world, the uninformed consumer merely knows that either one of the issuers or the service provider will carry out the currency conversion but cannot tell how the choice of the payment currency determines this.

consumers, viz. the choice of the payment currency instead of the choice between contracting with the DCC service provider or not.

⁵As will be explained, allowing for competition among service providers does not invalidate our conclusions.

⁶I.e., card-holders are generally aware of the "tourist trap," a useful term borrowed from Anderson and Renault (1999, p. 730).

We consider two settings, one in which DCC is prohibited (or unavailable for any other reason, e.g., because it has not yet been invented), and one in which no regulation applies. It is shown that, in either setting, the model admits a unique equilibrium in pure strategies. However, the market outcome depends dramatically on whether DCC is prohibited or not. Without DCC, we obtain the classic prediction of Bertrand competition that issuers bid each other down to marginal costs. With DCC, however, the equilibrium takes a somewhat unusual form. Specifically, the service provider benefits from the competition among the issuers, and optimally chooses a fee that *persistently exceeds the monopoly level*. In fact, this conclusion does not change if consumers' attention is determined endogenously.⁷

From a welfare perspective, the excessive fee chosen by the service provider depresses the volume of cross-currency payment transactions below the efficient level, thereby leading to losses in consumer surplus larger than the additional profits for the service provider. Although this might appear as a clear-cut case for regulation, e.g., in the form of a general prohibition of DCC, we argue that the practical problem is not easily resolved. Specifically, the analysis suggests that the advent of the DCC technology has created a global free-rider problem that stifles any national regulatory initiative and whose resolution requires the coordinating power of an effective supranational institution (such as the European Union). Our analysis might thereby help to explain why the regulatory response forcefully requested by consumer interest groups has, in many cases, not come

⁷Thus, we obtain a two-price equilibrium in the tradition of Salop and Stiglitz (1977). In contrast to their characterization of price dispersion, however, the service provider in our model sets its fee strictly above the monopoly level. Montez and Schutz (2021) have shown that pricing above the monopoly level may be part of a mixed-strategy equilibrium with ex-post inefficient inventory choice. However, their result does not extend to equilibria in pure strategies.

about up to the present day.⁸

Related literature. The present paper is related to three strands of literature. First, our analysis relates to the literature on *payment cards and platform competition*. Seminal work by Baxter (1983), Rochet and Tirole (2002), and Schmalensee (2002) explored the economic rationale and efficient level of interchange fees. Interchange fees are paid by the merchant’s bank to the card issuer and serve as a Coasean compensation for the benefits that merchants have when they accept electronic payments. While DCC is a revenue component from electronic payment that might matter for the efficient level of interchange fees, existing theoretical work has tended to avoid the explicit modeling of currency conversion.⁹ Second, our paper relates to the literature on *cognitive imperfections and choice complexity*.¹⁰ Indeed, in line with our main narrative, firms might strategically create complexity to reduce the proportion of informed consumers in the market (Carlin, 2009; Piccione and Spiegler, 2012; Chioveanu and Zhou, 2013; Ellison and Wolitzky, 2012; Spiegler 2014; Grubb, 2015). If all consumers are rational, however, firms do not shroud information in that sense. In contrast, our analysis suggests that framing, in the sense of transforming the choice set, may be profitable for merchants even if consumers are merely uninformed. Finally, our paper relates to the literature on *simultaneous search and equilibrium price dispersion*.¹¹ In their seminal work,

⁸It has long been understood that the market for credit cards is not very efficient (Ausubel, 1991; Brito and Hartley, 1995). However, the inefficiencies discussed in those papers relate to the level of interest rates on credit cards rather than to the level of fees charged for currency conversion.

⁹See, in particular, the surveys by Chakravorti (2010), Verdier (2011), or Rysman and Wright (2014). One reason for this might be that the revenue base of domestic transactions may be larger than that of cross-currency transactions — even though the DCC fee level tends to be much higher than the level of interchange fees.

¹⁰See Spiegler’s (2011) monograph and the survey by Armstrong and Vickers (2012), for instance.

¹¹See the surveys by Baye et al. (2006) and Anderson and Renault (2018).

Salop and Stiglitz (1977) assumed that uninformed consumers know the prices charged in the market but may not know which price results from their choices. The way in which we model competition follows that tradition. However, our model does not closely relate to Varian (1980). Indeed, while the model of sales may be seen as a variant of the all-pay auction, our game is not easily interpreted along these lines. E.g., we always find a unique equilibrium in pure strategies. At this writing, however, we have not found choice imposed under uncertainty being modeled as a revenue source in the existing literature.¹²

The remainder of this paper is structured as follows. Section 2 reviews the institutional background. The model is introduced in Section 3. Section 4 contains the equilibrium analysis. Section 5 derives implications for welfare and regulation. The assumptions of the model are further discussed in Section 6. Section 7 concludes. All formal proofs have been relegated to an Appendix.

2. Institutional background

2.1 Dynamic Currency Conversion

Dynamic Currency Conversion (DCC) is a financial service tailored for consumers that are in the process of authorizing transactions in an international context, e.g., when paying by card while traveling abroad, when withdrawing foreign currency from an ATM, or when authorizing a payment in international online shopping. In most cases, the currency option will be automatically offered at the point of interaction (POI) if the payment tool detects that the currency of the payment

¹²There are also some quite illuminating experimental papers on the issues that the present paper aims to capture in a formal model. In particular, Bouw (2016) conjectured a role for ambiguity aversion in a simulated ATM withdrawal. See also Gerritsen et al. (2014, 2017), and our discussion in Section 6.

card (which may be derived from the first six digits of the card number, i.e., from the *issuer identification number*) differs from the currency for the payment. The consumer may then choose to pay either in local currency or in the home currency.¹³

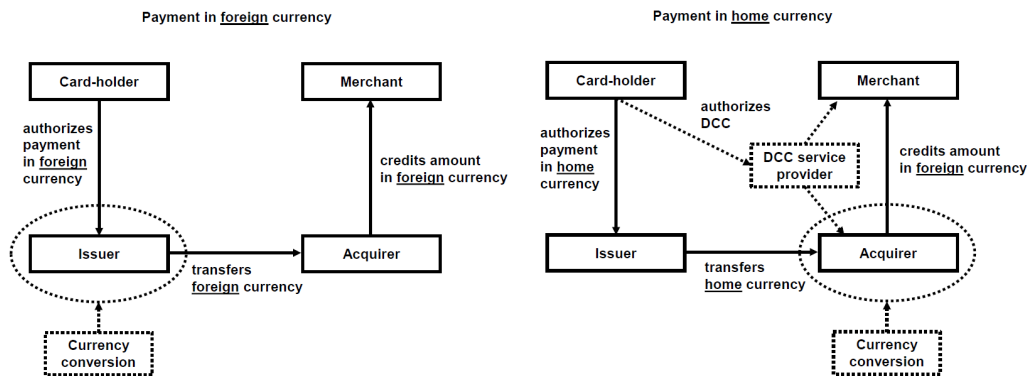


Figure 1. Settlement of international card payments

Figure 1, adapted from Rochet and Tirole (2002), illustrates the settlement of international credit card transactions, using the example of a card-holder paying for a purchase at a merchant’s check-out while traveling abroad. If the card-holder chooses to pay in foreign currency, then the conversion is carried out by the issuer.¹⁴ If, however, the card-holder chooses to pay in home currency, then the conversion is carried out by the so-called acquirer, i.e., by the merchant’s bank that processes

¹³The technical feasibility of DCC has been documented through patent filings around the turn of the millennium (cf. Barry, 2000, and Nicholls et al., 2005). According to Keck and Herman (2005), companies with a large share of international retail business, such as car rental companies, were the first to offer DCC in selected countries. Nowadays, there are numerous DCC service providers at the international level, including *Elavon*, *Euronet*, *Fexco*, *First Data*, *Monex*, *Planet Payment*, *Travelex*, and many others.

¹⁴More precisely, the currency conversion is carried out by the payment network that the issuer relies upon (e.g., in the case of credit cards, this could be Visa, Mastercard, Discover, or American Express). In general, issuers (e.g., banks or credit unions) set the terms of the card and provide financial backing, while networks process transactions among merchants, acquirers, and issuers. American Express and Discover serve as both issuers and networks.

the foreign currency transaction. Thus, merchant, acquirer, and service provider are three parties that earn a respective share of the revenues from DCC.

For card-holders, DCC offers the enticing possibility to obtain, at the POI, a legally binding price in the home currency as an alternative to the price in the foreign currency. There are some caveats, however. First, the payment tool may show only minimal information, such as the two currency labels.¹⁵ Second, even if more information is provided (e.g., if the tool shows the prices in the two currencies as well as and the exchange rate applied), the consumer still does not know which currency option is optimal unless the alternative exchange rate applied by the issuer is shown as well (but this is almost never the case). Third and finally, the payment tool is rarely explicit about the fact that the choice of the home currency may imply a contractual relationship with a foreign DCC service provider. For the merchant (ATM operator, online shop), DCC creates a source of additional revenues. Specific revenue components include foreign transaction fees, ATM network fees, currency conversion fees, DCC fees, and exchange rate margins, where the terminology may differ across institutions. These fees are collected but shared by the acquirer in response to the merchant's exclusive bargaining situation. Allegations that the currency choice has been "overruled" (Mastercard, 2017) suggest that DCC is indeed quite attractive for local merchants.¹⁶

According to de Groen et al. (2018), DCC transactions generate the highest fees per transaction, followed by surcharges and interchange fees.¹⁷ E.g., Elavon

¹⁵E.g., in the introductory example, the terminal might show the message "Do you wish to pay in USD or in MXN?" and request the selection of one of the two options.

¹⁶In the main analysis, we will abstract from this institutional feature and assume instead that the service provider is the sole decision maker in this alliance. See, however, Section 6 for an extension in which several service providers compete for their role in the transaction business.

¹⁷However, interchange fees for cross-border payment card transactions may differ from those applied in national transactions (Vickers, 2005, p. 10).

processes more than five billion transactions, valued at nearly \$450 billion, around the world per year. Visa and Mastercard generated about \$7.2 billion and \$4.9 billion revenues from international fees in 2018, respectively.¹⁸

2.2 Consumer interest groups

Soon after its inception, DCC was under heavy attack from consumer interest groups on the grounds that it implies a substantial service fee on top of an exchange rate that tends to be quite disadvantageous (e.g., Keck and Herman, 2005). This initial critique has never really ebbed away. In a recent position paper of the European consumer organization BEUC, Allix and Aliyev (2017, p. 2) summarized the complaint as follows: “When choosing the DCC option in card payments and ATM withdrawals, the consumer is financially worse off in practically every single case. It is almost impossible for a consumer to make an informed decision when presented with the DCC option, because of various nudging strategies put in place by the DCC service providers and merchants.”¹⁹ The same study surveys a large number of case studies, covering issuer countries such as Germany, Norway, and the UK. These studies unequivocally confirm the view that making use of DCC is generally expensive, with costs of 12 percent over the next best option not being uncommon. A recent follow-up study by Stiftung Warentest (2019) found the extreme case of 13.7 percent cost differential from paying in euro rather than in koruna at an ATM located in the Czech Republic.²⁰ There are numerous media

¹⁸See Visa (2019, p. 15) and Mastercard (2019, p. 44).

¹⁹The following quote from Flywire (2018) might help to illustrate such nudging strategies. “Does the country of issuance of my credit card matter? — Yes, it’s important that you pay with a credit card issued in your home country, as we expect our customers to use cards denominated in their currencies. Your credit card will be charged the amount, and in the currency of, your payment request. — If a different currency is used, your bank will need to convert the funds from your card to the currency selected in the payment request in order for us to receive it. This will result in additional charges for you.”

²⁰Even the 1-3 percent fees that are regularly charged by issuers for international transactions

reports and studies that ask why the ongoing scandal is not finally brought to an end.²¹

In sum, there is quite some evidence that DCC is indeed used to extract excessive consumer rents. The precise way in which this is feasible, however, is not particularly well-understood. Below, we introduce an analytical framework that provides a rationale for how the rent extraction is accomplished, why competition for currency-exchange services does not eliminate the problem, and why the ongoing complaints have not triggered sufficient action by regulators.

3. The model

This section introduces our analytical framework, which may be described as a Bertrand model featuring groups of consumers that differ in their costs of acquiring information (Salop and Stiglitz, 1977). Our departure from the standard model of simultaneous search is the assumption that consumer's ignorance takes a particular form.

3.1 Firms competing for currency conversion

Considered is a model of price competition involving $n \geq 2$ issuers, denoted by $i \in N \equiv \{1, \dots, n\}$, and a single service provider, denoted by $i = S$. Each of the $(n + 1)$ competitors, $i \in N_S \equiv N \cup \{S\}$, independently and simultaneously chooses a fee $f_i \geq 0$ for currency conversion. Here, the fee variable is understood broadly, so as to represent the total costs of currency conversion for the consumer. Issuers and service provider are assumed to have access to the same technology for carrying out the currency conversion. For convenience, the marginal costs of

have been considered abusive (cf. Southern District of New York, 2003).

²¹See, e.g., West (2015), Bouyon and Krause (2018), or Goyens (2018), among many others.

providing the conversion service are assumed to be constant and equal to $c \geq 0$. Moreover, the service is a homogeneous product, i.e., there is no differentiation across competitors.²² Both the issuers and the service provider are risk-neutral and maximize expected profits.²³

3.2 Consumer choice

There is a continuum of consumers. We assume that each consumer may select a pair $\gamma = (i, \mu)$ from the set $N \times \{H, F\}$, where $i \in N$ and $\mu \in \{H, F\}$ refer to the card-issuing firm and the payment currency, respectively. The outside option of not requesting any currency conversion will be denoted by γ_0 . We will interpret $\mu = H$ as choosing the home currency, and $\mu = F$ as choosing the foreign currency. Next, we specify how the consumer's choice determines which firm will carry out the conversion. For this, we assume that there are two states of the world, collected in the state space

$$\Omega = \{\omega_T, \omega_C\}. \quad (1)$$

The *true state* of the world, ω_T , corresponds to the actual implementation of DCC described in the Introduction. Thus, in the true state, choosing $\mu = H$ (choosing $\mu = F$) implies that the conversion is carried out by the service provider S at a price of f_S (by the issuer i at a price of f_i). However, in the *counterfactual state*, ω_C , the roles of the issuer and the service provider are exchanged, i.e., choosing $\mu = H$ (choosing $\mu = F$) implies that the conversion is carried out by the issuer i at price f_i (by the service provider S at a price of f_S). In the case $\gamma = \gamma_0$, there is no currency conversion, and the consumer is not charged any fee (e.g., because

²²The case of imperfect competition will be discussed in Section 6.

²³This specifies the objectives of the $(n + 1)$ competitors in the case of $n = 2$ issuers. However, to eliminate equilibria of limited interest when $n \geq 3$, we assume that, among fees that maximize expected profits, each competitor chooses the fee that maximizes market share.

the payment is settled in cash or there is no transaction in the first place).

3.3 The informational basis of consumer choice

Consumers may be of two types, informed and uninformed. We denote by $\alpha \in [0, 1]$ the fraction of the consumer population that is informed. Informed consumers know the true state of the world. Thus, the informed consumer knows how the payment currency μ determines the firm that carries out the currency conversion. Therefore, the informed consumer's decision boils down to choosing an element from the set $N_S \cup \{\gamma_0\}$.

For the uninformed consumers, however, there is uncertainty regarding how the choice of the payment currency μ determines which firm carries out the conversion. In our framework, the uninformed consumer merely knows that this will be either the issuer of the chosen credit card or the service provider. Thus, despite being informed about the fees for currency conversion charged by all issuers and the service provider, the uninformed consumer does not know the state of the world, and consequently, faces a decision under incomplete information. In particular, the uninformed consumer does not know if the fee applicable to the transaction will be f_S or f_i .

For $\alpha = 1$, all consumers are informed, and the $(n + 1)$ competitors adhere to marginal cost pricing in straightforward extension of Proposition 1. We therefore assume throughout that $\alpha \neq 1$.

3.4 Assumptions on demand

Let $D_I(f)$ and $D_U(f)$, respectively, denote the demand of the informed and uninformed consumers at the (expected) fee level $f \geq 0$.²⁴ Given that each consumer

²⁴Assuming that all consumers possess the same maximum willingness-to-pay, as Salop and

requests either one transaction or no transaction, demand corresponds to the size of the subpopulation of consumers that possess a willingness-to-pay weakly exceeding the fee. To ensure that the profit functions of the competing firms are well-behaved, we impose the following assumption on the differentiability and shape of the demand functions.

Assumption 1. (Demand for currency conversion)

(i) $D_I \geq 0$ and $D_U \geq 0$ are weakly decreasing, continuous, as well as twice differentiable at positive demand levels, with $D'_I < 0$ and $D'_U < 0$;

(ii) $D_U(c) > 0$;

(iii) $D''_U D_U - D'^2_U \leq 0$ at positive demand levels.

Assumption 1 contains no surprises. By condition (i), both demand components are nonnegative, weakly decreasing, and continuous; in addition, D_U and D_I are assumed twice differentiable and strictly downward-sloping when positive. In particular, each demand component may either vanish at some finite level or stay positive at arbitrary high levels. Condition (ii) requires that there are gains from trade for some of the uninformed consumers. Finally, condition (iii) says that D_U is logconcave in the interval where $D_U > 0$. This condition holds, in particular, if D_U is concave at positive demand levels. Clearly, however, Assumption 1 is also consistent with convex demand.²⁵

Stiglitz (1977) do, would simplify the equilibrium analysis, but the welfare analysis would be misleading: There is no inefficiency when consumers have identical valuations.

²⁵Using the notion of generalized concavity (Caplin and Nalebuff, 1991), Assumption 1 may be further relaxed without affecting our main conclusions. See Example 2 below for illustration, and Ewerhart and Li (2020) for a formal treatment.

4. Equilibrium analysis

This section studies the equilibrium set of the non-cooperative pricing game introduced above. Throughout, we restrict attention to Nash equilibria in pure strategies. We first consider the market without DCC, then analyze the case with DCC, and finally show that the service provider always charges a fee above the monopoly level.

4.1 The market without DCC

A natural starting point for the analysis is the case in which the service provider has no access to the market. Thus, the currency conversion is known to be carried out by the chosen issuer, and each consumer effectively chooses from the set $N \cup \{\gamma_0\}$. As has been discussed, this scenario corresponds either to a situation in which a regulator prohibits the use of the technology, or else to a point in time at which the DCC technology was still unavailable (i.e., more than two decades ago).

As all fees are public information, and the distinction between uninformed and informed is eliminated, it is immediate to see that all consumers are able to select an issuer that offers the lowest fee

$$\underline{f} = \min\{f_1, \dots, f_n\}. \quad (2)$$

This observation reflects our general presumption that consumers are well-informed about card conditions and find it easy to choose their preferred issuer for international payments. In the case of a tie, we assume that a consumer is equally likely to choose any of the best offers.²⁶ Therefore, the model without DCC is seen to be equivalent to a traditional Bertrand game with constant marginal costs. The

²⁶Provided that any competitor tying on the lowest fee expects a positive market share, the way in which ties are resolved does not matter for the equilibrium prediction.

following result should, consequently, not be too surprising.

Proposition 1. (Bertrand competition) *Impose Assumption 1, and suppose that the service provider has no access to the market. Then, $f_1 = \dots = f_n = c$, i.e., all the issuers set their fees equal to marginal costs.*

Proof. Omitted. \square

4.2 The market with DCC

Suppose next that the service provider has access to the market. We will show that, in this case, the service provider's ability to frame the choice (possibly in collusion with the merchant) implies that there is no true competition between the issuers and the service provider.

Following Salop and Stiglitz (1977), we assume that the uninformed consumer randomizes uniformly across payment currencies, making it equally likely to have the currency conversion carried out by the chosen issuer or by the service provider.²⁷ Thus, the expected fee for an uninformed consumer is given as

$$E[f] = \frac{1}{2} (f_S + \underline{f}). \quad (3)$$

Note that the condition for demanding the service, viz. that the uninformed consumer's willingness-to-pay must weakly exceed $E[f]$, marks the difference to existing models of Bertrand competition.

The following result characterizes the asymmetric equilibrium in the price-setting game with DCC service provider.

²⁷See also Diamond (1971) and Braverman (1980). In Section 6, we will review microfoundations and evidence of randomized choice.

Proposition 2. *Impose Assumption 1, and suppose that the service provider has access to the market. Then, there is a unique equilibrium, in which the service provider charges*

$$f_S^* = \arg \max_{f_S \geq 0} \frac{f_S - c}{2} \cdot D_U \left(\frac{f_S + c}{2} \right) \quad (4)$$

strictly above marginal costs, while the issuers all set their fees equal to marginal costs.

Proof. See the Appendix. \square

Thus, when admitted to the market, the service provider sets a fee strictly above marginal costs, and makes a positive profit. Moreover, the anti-competitive two-price equilibrium is the unique equilibrium of the pricing game. Intuitively, the fact that uninformed consumers randomize creates a market segment that is captive for the service provider. As a result, the service provider finds it optimal to forgo the meager revenues from informed consumers, focusing instead exclusively on benefiting from the suboptimal choices made by the uninformed consumers.²⁸

In comparison with Varian (1980), however, there is a crucial difference regarding the condition for purchase by uninformed consumers. Specifically, in the model of sales, uninformed consumers purchase from a randomly chosen store provided that the *observed* price in that store is low enough. In our setting, however, uninformed consumers, while likewise randomizing, request the service provided that the *expected* price is low enough. Put differently, the consumer knows the

²⁸The fact that the service provider earns a positive profit relates our paper to the literature on the Bertrand paradox. E.g., as pointed out by Dastidar (1995), the assumption of strictly convex costs may be used to obtain an equilibrium in a Bertrand game with positive profits. However, our set-up does not require strictly convex costs. Relatedly, Spulber (1995) noted that asymmetric information regarding rivals' costs may allow to achieve positive profits. Again, our argument differs.

transacting firm in the model of sales but may not know it in our framework. It is this difference that dramatically changes the nature of the equilibrium.

As discussed in Armstrong and Vickers (2012), assuming cognitive imperfections on the part of the consumers usually implies an externality between rational and naïve consumers. E.g., the increase of the share of rational consumers in the population may force firms to offer more competitive prices, making it harder to exploit naïve consumers. However, in our setting, there is no such externality. Uninformed consumers are exploited by the service provider regardless of how many informed consumers are around.²⁹

4.3 Pricing above the monopoly level

Suppose for the moment that a single firm offers the service of currency conversion to the uninformed segment of the consumer population. In that situation, the firm solves the problem

$$f^M = \arg \max_{f \geq 0} (f - c)D_U(f). \quad (5)$$

In analogy to the proof of Proposition 2, one can show that under Assumption 1, the objective function in (5) admits a unique global optimum that is interior and, hence, characterized by the first-order condition

$$(f^M - c)D'_U(f^M) + D_U(f^M) = 0. \quad (6)$$

We refer to f^M as the *monopoly fee*. The following result was somewhat unexpected to us.

Proposition 3. *Impose Assumption 1. Then, the service provider sets a fee strictly above the monopoly price level, i.e., $f_S^* > f^M$.*

²⁹However, if the competition among issuers is sufficiently imperfect, the externality may reappear because the service provider may then find it profitable to compete also for the informed demand.

Proof. See the Appendix. \square

What is the intuition behind Proposition 3? As noted above, the randomization of uninformed consumers creates a captive market segment on which the service provider chooses to focus exclusively. Now, the uninformed consumers in that segment expect to pay the service provider's fee only with probability one half, and otherwise expect to benefit from the competition between the issuers. This averaging effect softens the impact of an increase in the service provider's fees on uninformed demand, i.e., demand in the captive segment is strictly less elastic than in a monopolistic market.³⁰ With the service provider's trade-off biased in that way, the profit-maximizing fee set by the service provider strictly exceeds the monopoly level.

The proof presented in the Appendix derives Proposition 3 by considering a parameterized model that embeds both our model and a hypothetical situation in which the service provider is a monopolist in the market for uninformed demand. The result is then obtained from an analysis of cross-derivatives, i.e., by applying methods of monotone comparative statics. There is, however, a potentially more intuitive (even though less conventional) way to validate the conclusion of Proposition 3. By directly comparing the optimization problem of the service provider (4) with that of the monopolist (5), we see that the service provider optimally sets

$$f_S^* = 2f^M - c. \quad (7)$$

E.g., if $c = 0$, the fee charged by the service provider is just twice as large as the

³⁰The elasticity-reducing effect of randomized demand is particularly evident in the example of isoelastic demand that will be discussed below as Example 2.

monopoly fee. Rewriting relationship (7) yields

$$f^M = \frac{f_S^* + f}{2}, \quad (8)$$

i.e., the service provider sets a fee f_S^* such that the uninformed consumer's expected costs for the currency conversion precisely equal the monopoly fee. Given that the issuers bid each other down to marginal costs, this indeed implies that $f_S^* > f^M$.³¹

We illustrate the conclusion of Proposition 3 with two examples.

Example 1. (Linear demand) Suppose that uninformed demand is given as

$$D_U(f) = \begin{cases} \left(1 - \frac{f}{f^{\max}}\right) \cdot D^{\max} & \text{if } f \leq f^{\max} \\ 0 & \text{if } f > f^{\max}, \end{cases} \quad (9)$$

where $D^{\max} > 0$ and $f^{\max} > c$ are exogenous parameters. Then, the monopoly price is $f^M = \frac{f^{\max} + c}{2}$, while the equilibrium fee chosen by the service provider is strictly higher, viz. $f_S^* = f^{\max}$.³²

In the following example, we compare the mark-up of the monopolist with the mark-up charged by the service provider.

Example 2. (Isoelastic demand) Suppose that

$$D_U(f) = f^{-\eta}, \quad (10)$$

³¹As will be seen in Section 6, endogenizing the attention of uninformed consumers on the potential costs of using DCC even exacerbates this effect.

³²This example extends in a straightforward way to a more flexible specification of D_U in which the term in the brackets on the right-hand side of equation (9) is taken to the power of any $\gamma \in (0, \infty)$. In particular, as demand is strictly concave for $\gamma < 1$, the conclusion of Proposition 3 can be illustrated also in that case.

where $\eta > 1$ is the elasticity of uninformed demand.³³ To ensure a finite optimum, we assume that $c > 0$. Then, the monopolist's mark-up over marginal costs as a percentage of price satisfies the standard relationship

$$\frac{f^M - c}{f^M} = \frac{1}{\eta}, \quad (11)$$

whereas the service provider's mark-up is characterized by

$$\frac{f_S^* - c}{f_S^*} = \left(1 + \frac{c}{f_S^*}\right) \cdot \frac{1}{\eta} > \frac{1}{\eta}. \quad (12)$$

In particular, we get that $f_S^* > f^M$, as predicted by Proposition 3.

5. Welfare analysis and regulation

In this section, we first derive the implications of DCC for producer surplus, consumer surplus, and aggregate welfare. The results are then used to identify a regulatory dilemma.

5.1 Producer surplus

As has been seen above, the service provider is in a very strong position. In fact, with respect to price, the service provider's situation looks even more comfortable than that of the ordinary monopolist. With respect to quantity, however, the service provider sells strictly less than the volume brought to the market by the monopolist. Indeed, the service provider sells just half of the monopolist's output. It turns out that, in terms of expected profits, these two effects just balance out. Thus, regardless of the shape of uninformed demand, the service provider realizes precisely the expected profit of an ordinary monopolist.

³³While the isoelastic specification does not satisfy Assumption 1, the proofs can be easily seen to extend to this case. For details, see the Appendix.

Proposition 4. *The service provider realizes expected profits equivalent to monopoly profits in the uninformed segment of the market for currency conversion.*

Proof. See the Appendix. \square

In the Appendix, we offer another proof based on the idea of convexification. In line with the substitution argument outlined following the proof of Proposition 3, however, we may offer an alternative proof of Proposition 4 as well. For this, recall that the service provider sets f_S^* such that the uninformed consumer's expected costs for the currency conversion equal the monopoly fee, i.e.,

$$f^M = \frac{f_S^* + \underline{f}}{2}. \quad (13)$$

Using this observation, it may be even more straightforward to verify that the service provider's expected profit must be the same as that of a monopolist in the uninformed market.

5.2 Consumer surplus and aggregate welfare

Putting the pieces together, our analysis shows that the advent of the DCC technology at an otherwise competitive market for currency conversion may cause a substantial loss in social welfare.

Corollary 1. *The market admittance of a DCC service provider lowers consumer surplus and aggregate welfare to the same degree as the introduction of a monopoly in the uninformed market segment.*

Proof. Immediate from Proposition 1 and relationship (8). \square

Intuitively, the service provider's monopoly power originates from the ability to frame the card-holder's problem. Asking for the payment currency obfuscates the

fact that the actual choice concerns the firm from which the service is purchased. The framing also bears the potential of confusing the decision maker because the option of choosing the home currency, which may be focal for many consumers, implies accepting the offer of the foreign service provider.

Despite its theoretical nature, Corollary 1 may be a strong statement for the applied theorist. We will therefore critically review the assumptions underlying our analysis in Section 6. Before we do that, however, it seems appropriate to derive the implications for policy making on DCC.

5.3 An international free-rider problem

Corollary 1 seems to suggest that regulators should find it straightforward to agree to globally prohibit DCC.³⁴ However, this conclusion is flawed as it ignores the international dimension of the problem. Specifically, for a national regulatory authority, the identified gain in producer surplus arising from international payments is of a domestic nature, while the corresponding loss in consumer surplus from such transactions is of an entirely foreign nature. For instance, in the introductory example, the Mexican regulator might listen more carefully to local hoteliers than to U.S. consumer interest groups. Thus, national supervisors should wish to prohibit DCC abroad but not domestically. We argue that this lack of reciprocity, which we could not see reflected in the written accounts on DCC, creates a global free-rider problem that is not easily resolved.

Supranational regulators in the European Union may be in a similar situation as national regulators, given that the large majority of member countries uses the euro as official currency. However, on February 14, 2019, the European Parliament

³⁴Alternatively, regulators could promote mandatory disclosures, POI competition among service providers, or voluntary self-restriction by merchants.

adopted a proposal implementing additional transparency for currency conversion in cross-border payments *between two EU countries*.³⁵ This illustrates that the institutions of the EU are able to resolve the free-rider problem within member states. However, the restriction to EU countries shows that regulation on a global level is less straightforward to achieve.

We conclude the discussion with two caveats. First, suppose that the DCC model is embedded into a Rochet-Tirole (2002) framework, so that issuers would request interchange fees from acquirers. These probably could be differentiated with respect to currency. Then, a share of the producer surplus would end up in the hands of the issuers, which might mitigate (but not eliminate) the problem. Another caveat is that, ultimately, the higher profits from DCC might help to provide stronger incentives to invest in socially desirable payment infrastructure (e.g., Reisinger and Zenger, 2019). However, the extent to which these considerations matter depends on the relative bargaining power of the involved parties, which is an empirical issue that has, to our knowledge, not been investigated so far.

6. Discussion

In this section, we discuss our main conclusion that DCC is socially undesirable but hard to regulate. Our arguments below may (but need not) be supported by formal arguments.

6.1 Microfoundation of randomization

We have argued above that consumers randomize uniformly over equivalently perceived optimal alternatives. Consumers may choose to consciously randomize if they are *ambiguity averse*. For instance, according to the multiple-priors model

³⁵See European Commission (2018).

(Gilboa and Schmeidler, 1989), the decision maker ex-post adopts the prior probability distribution that minimizes expected utility. One possible interpretation is that the individual is conservative and focuses on the worst-case scenario, as if playing against Nature. Provided that ambiguity aversion is understood this way, the set of priors considered possible may be effectively reduced by randomly choosing one of the available options. Along these lines, conscious randomization may indeed be seen as a rational response to ambiguity (Raiffa, 1961; Saito, 2015; Ke and Zhang, 2020), and one may follow this logic to strengthen the uniqueness proposition in our prediction.

To see this formally, let $p_T \in [0, 1]$ denote the uninformed consumer's prior probability that the true state ω_T obtains. For convenience, the set of beliefs in the multiple-priors model is assumed to be the entire set of feasible beliefs, i.e., $P = \{p_T \in [0, 1]\}$. Then the unique optimal response for the uninformed consumer entails randomization. More precisely, if $f_S \neq \underline{f}$, then an uninformed consumer not choosing γ_0 finds it strictly optimal to randomize uniformly across the currency options $\mu \in \{H, F\}$. To see this, it suffices to note that

$$\frac{1}{2}p_T + \frac{1}{2}(1 - p_T) = \frac{1}{2} \quad (p_T \in P). \quad (14)$$

I.e., a consumer uniformly randomizing over currencies eliminates the ambiguity entirely.³⁶ If one alternative yields a lower fee than the other in state ω_T , and

³⁶In the Gilboa-Schmeidler framework, ambiguity aversion is modeled as pessimism with respect to a set of Bayesian beliefs. E.g., the decision maker (DM) may not know how many marbles in the urn are black and how many are red. Uniform randomization over urns transforms each belief into a uniform distribution. For instance, via randomization, DM draws from an urn with 30 black and 70 red marbles with probability one half, and from an urn with 70 black and 30 red marbles with the same probability one half, which amounts to drawing a marble from a single urn with $30 + 70 = 100$ black marbles and $70 + 30 = 100$ red marbles. It is easy to see that the arithmetic is similar if the urn that we started from contains instead 40 black and 60 red marbles. Thus, a set of beliefs is reduced to a uniform point belief. Along these lines, ambiguity is eliminated by randomization.

vice versa in state ω_C , then giving equal weight to both alternatives is the unique optimal strategy.³⁷

6.2 Rational inattention

Boundedly rational consumers might choose to be *rationally inattentive* to the preparation of their foreign-currency transactions (Matějka and McKay, 2012). In a stochastic environment, if processing information is costly, the optimal choice of the payment currency may result with a probability strictly between one half and one, i.e., the choice may appear random but have a probabilistic tendency towards the optimal solution. In that case, both the market share of the service provider and the level of the abusive fee f_S would depend on the degree of financial illiteracy (i.e., on the costs of acquiring information) in the population of consumers.

Formally, starting from an uninformed prior, and assuming stochastic costs as one might expect in a situation where payments are made in different foreign currencies over time (cf. the discussion in Grubb, 2015, p. 315), the service provider's optimal fee in a model with rational inattention solves

$$f_S^\lambda = \arg \max_{f_S \geq 0} \frac{(f_S - c)e^{-f_S/\lambda}}{e^{-f_S/\lambda} + e^{-c/\lambda}} \cdot D_U \left(\frac{f_S e^{-f_S/\lambda} + c e^{-c/\lambda}}{e^{-f_S/\lambda} + e^{-c/\lambda}} \right), \quad (15)$$

where $\lambda > 0$ measures the consumer's costs of information acquisition. Recycling the arguments used in the proof of Proposition 2, this problem can be shown to possess precisely two solutions for any $\lambda > 0$, with the property that $f_S^\lambda \rightarrow f_S^*$ as $\lambda \rightarrow \infty$ (regardless of the choice of the solution). With rational inattention modeled that way, our conclusions do not change. In fact, given that consumers expect

³⁷Alternative microfoundations include rational inattention, as discussed in the next subsection, and randomness of consumer preferences. Evidence of randomized choice has been provided by Agranov and Ortoleva (2017) and Dwenger et al. (2018), in particular. There is also some anecdotal evidence in the sense that some of our colleagues to whom we presented our analysis "admitted" having had recourse to randomization when faced with the choice of currency in electronic payment.

to pay f_S^λ with lower probability than in the base model, the service provider's optimal fee in the model with rational inattention will be predicted to be *even higher* than f_S^* . However, the share of the uninformed consumers that take the wrong decision correlates with the costs of information acquisition. The overall effect on the service provider's expected profit is again neutral. I.e., regardless of λ , the service provider will realize the monopolist's profit.³⁸

6.3 Feedback and learning

One might wonder that consumers would learn how to choose over time. In fact, Varian (1980) criticized the Salop-Stiglitz framework precisely by arguing that persistently higher prices for homogeneous products are implausible. Certainly, consumers easily learn prices for goods and services they consume in their home town in a regular fashion, like a bottle of milk or a haircut. However, learning from intermittent financial transactions may be less straightforward.³⁹ E.g., if a souvenir is bought in a foreign country at a variable exchange rate, then a consumer may lack any point of reference that would allow to judge if the fees for the currency conversion would have been lower if the alternative payment

³⁸These conclusions follow from rewriting problem (15) as

$$f_S^\lambda = \arg \max_{f_S \geq 0} \frac{f_S - c}{1 + e^{(f_S - c)/\lambda}} \cdot D_U \left(\frac{f_S - c}{1 + e^{(f_S - c)/\lambda}} + c \right).$$

A straightforward substitution argument delivers the relationship

$$f_S^* - c = \frac{f_S^\lambda - c}{1 + e^{(f_S^\lambda - c)/\lambda}}.$$

This relationship can be shown to generally admit precisely two solutions for f_S^λ , both of which necessarily are strictly larger than f_S^* . Multiplicity arises because attention is nonlinear in fees. By the same substitution argument, the service provider's problem with endogenous attention is seen to be equivalent in profits to the monopolist's problem. Further details are available from the authors on request.

³⁹Indeed, Ausubel (1991) empirically validated that interests on loans on credit cards may be sticky at a high level.

currency had been chosen. Indeed, the monthly credit card invoice may provide only very limited information. Thus, in the situation at hand, the lack of feedback arguably slows the learning down to some extent. Notwithstanding, learning the state of the world is, of course, a possibility for consumers that travel abroad more frequently (like the authors of this article). What can be anecdotally observed, too, is that in environments where consumer feedback is feasible (e.g., at leading online market places), transparency about the DCC option is more commonplace than in environments where reputational concerns are less important (say in airport cabs). Empirical research on such issues seems to be missing, however.

6.4 Countermeasures taken by the issuers

As explained in Section 5, national regulators and consumer protection authorities may find it difficult to stop the ripoff that is happening in foreign jurisdictions. Often, they cannot do much more than warn consumers in the abstract. Issuers and payment networks, however, can take countermeasures. We found this to happen in a variety of ways. One dimension is *moral suasion* vis-à-vis merchants' banks. E.g., Mastercard (2017) has introduced a performance rewards program for acquirers. A second dimension is *exclusive contracting*, even if that means taking on substantial legal risks. E.g., the Australian Federal Court had ordered Visa to pay a record A\$18m penalty for breaching exclusive dealing laws by preventing banks and third party providers from rolling out DCC services to new merchants during 2010. A third and final dimension in which issuers and networks seek to win the competition is by *influence activities*. Issuers may, e.g., suggest the choice of local currency to their customers.⁴⁰ Thus, issuers and networks do perceive service

⁴⁰E.g., a major Swiss bank advised its clients as follows: “Our tip: Pay in the currency of the country in question—that way you will generally benefit from a more favorable exchange rate.”

providers are competitors and do what is in their might to raise their market share in the market for currency conversion.

6.5 Search costs, imperfect competition, and product differentiation

The striking conclusion of Proposition 3 is derived under the assumption that issuer fees are close to marginal costs in equilibrium. However, marginal cost pricing among issuers might be a fragile equilibrium if small but positive search costs have the potential to trigger an unraveling of the market in analogy to the Diamond Paradox.⁴¹ While we of course acknowledge the general validity of this argument, we believe that consumers do not find it difficult to compare conditions for credit card transactions. In particular, there are publicly available websites that allow consumers to easily identify issuers with advantageous conditions for them. In contrast, comparisons of DCC service providers are not commonly found on the internet, maybe because the consumer is rarely asked to choose between two service providers. For similar reasons, a national regulator will find it easier to implement a price cap on its domestic issuers than on service providers that are distributed globally over numerous jurisdictions or currency areas.

It is perceivable, however, that competition between issuers is less than perfect, or similarly, that there is collusion among issuers.⁴² If this happens, it seems natural to expect that the service provider's position weakens, resulting in a lower fee and lower profits for the service provider. The reason is that the service provider sets its fee f_S such that its average with \underline{f} corresponds to the monopoly price in the uninformed market. Therefore, when \underline{f} raises above marginal costs as a result of

A potential problem with such messages, however, may be that the issuer is advertising its own business.

⁴¹See Diamond (1971) and, for discussion, Stiglitz (1979).

⁴²For example, customers may care more about domestic transactions than about international transactions, but these services are tied from the consumer's perspective.

imperfect competition among issuers, f_S^* will decline. Moreover, using the envelope theorem, it is easy to check that

$$\frac{\partial}{\partial f} \left\{ \frac{f_S^* - c}{2} D_U \left(\frac{f_S^* + f}{2} \right) \right\} = \frac{f_S^* - c}{4} D'_U \left(\frac{f_S^* + f}{2} \right) < 0, \quad (16)$$

i.e., the service provider's expected profit declines. In fact, provided that the share of informed consumers is sufficiently large, the service provider might find it profitable to charge a fee below the monopoly level so as to attract those informed consumers. However, even in the weakened position, the service provider will charge a fee above the monopoly level as long as the equilibrium fee level charged by the issuers stays sufficiently low to make it unattractive for the service provider to target the informed consumers.

Finally, as mentioned in the Introduction, the currency conversion offered through a DCC service provider is not entirely identical to the currency conversion that is carried out by a card-issuer. If, for example, the service provider chooses to show an amount of the home currency, the exchange rate is fixed at the time of the interaction. From the consumer's perspective, this eliminates the exchange rate risk between payment and settlement, i.e., over a period of usually very few business days. Moreover, the consumer may find the information regarding the definite amount useful.⁴³ This sort of product differentiation might, therefore, provide some economic rationale against a general ban of DCC. However, unless the transaction contains a very weak currency, it seems unlikely that, under full cost transparency, consumers would be willing to accept a substantial mark-up in

⁴³However, much of this usefulness is owed to the fact that the service provider (that usually operates the payment terminal) fails to show the *expected* amount to be charged by the issuer. This information could probably be easily provided, as is evident from the positive example of travel platforms that state a price estimate in the consumer's currency but inform at the same time that the payment will be settled in local currency at the end of the trip.

exchange for these limited benefits.

6.6 Competition among service providers

A natural question to ask is why competition among service providers would not eliminate the problem of excessive fees. To answer this question, suppose that $k \geq 2$ service providers compete in an *ex-ante* stage before the payment stage, so that only one service provider is visible to the consumer. Suppose also that each service provider offers a sharing rule (between the merchant and the service provider) for the fees earned through the currency conversion. In that case, service providers would bid each other down to marginal costs, and leave all the revenues from DCC to the merchant. Thus, the conclusions of our analysis would not change.⁴⁴ In another variant of our model, the merchant might consider making more than one DCC service provider visible to the consumer, in which case service providers would compete at the payment stage. This, however, is not plausible, as it has the potential of reducing the merchant's own share in the revenues from DCC. Thus, in line with the evidence, the discussion suggests that competition between service providers is unlikely to play out to the benefit of the customer.

7. Conclusion

The analysis conducted in the present paper adds support to the view that DCC service providers are able to extract substantial rents from cross-currency consumers by imposing an opportunistically framed choice upon them. By withholding crucial information that would allow an uninformed and possibly inattentive consumer to make a good decision, the service provider creates an environment in

⁴⁴The only change necessary to reflect the new assumption would be that the merchant takes the role of the service provider.

which the inferior option will be chosen with positive probability. Provided that competitive forces work among domestic issuers and there is a lack of informative feedback following the interaction, this allows the service provider to persistently charge fees strictly above the monopoly level. The specific technological environment of cross-currency payment may therefore overturn, and even reverse, the usual welfare-enhancing effect of competition. Policy responses are available, in principle, but our results suggest that a free-rider problem might make it hard to reach an international agreement. Our analysis thereby provides an explanation of why the DCC debacle has been ongoing for so many years despite the sizable body of evidence that has been collected by consumer interest groups.⁴⁵

Our analysis complements the findings of the literature on interchange fees in payment networks. However, our observation regarding the non-competitive nature of DCC might also have implications for the level of interchange fees. Specifically, to the extent that issuers possess market power vis-à-vis merchants, interchange fees resulting from international transactions should reflect the share of the profits from DCC that an issuer is able to extract (as a fourth party besides merchant, acquirer, and service provider). Thus, our analysis suggests also an alternative explanation for why interchange fees have empirically been found to be

⁴⁵With the introduction of Regulation 2021/1230, the EU Commission has decided against a complete ban of DCC and instead made its use contingent on more comprehensive consumer information at the POI. To our understanding, however, the informational requirements may still not allow the consumer to make an informed decision because the *direct comparison* of effective costs, e.g., in terms of best-possible estimates of the total in home currency on the consumer's account statement, both for the issuer's and for the service provider's offer, is not part of the policy amendments. We further believe that the new regulation does not properly address the problem of the missing feedback loop (Section 6.3), so that the card-holder is thrown into cold water each time again. Neither does the regulation appear to diminish the service provider's monopoly power (Section 6.6) in any way. Time will show if the regulatory measure taken are as effective as anticipated by the commission proposal.

higher than the efficient level.⁴⁶

Our analysis does not address all aspects of DCC. For example, by assuming that individual consumers have a unit demand for currency conversion, we have ignored the fact that some of the processing costs arise per transaction while others are linked to the amount. It is questionable, however, if an analysis of this extension would lead to additional conclusions. Further, it might be of interest to study how competition among merchants interferes with the service provider's ability to extract extraordinary rents. Again, we believe that such competition should play only a subordinate role in the global free-rider problem identified in the present analysis (in particular because, for the merchant, the competitive gains from announcing that DCC is not applied are probably negligible compared to the revenues from DCC). We will leave a more careful analysis of such issues for future work.

Appendix: Proofs

This appendix contains the proofs of the formal results of this paper, as well as details on Example 2.

Proof of Proposition 2. The proof has five steps.

A.1 Profit functions

We start by deriving firms' expected profits from an informed consumer. Provided that an informed consumer's willingness-to-pay weakly exceeds the lowest fee in the market, i.e., $\min(\underline{f}, f_S)$, the expected profit of issuer $i \in N$ from that consumer

⁴⁶See, e.g., Wright (2012) and Bedre-Defolie and Calvano (2013).

is given as

$$\Pi_i^I(f_1, \dots, f_n; f_S) = \begin{cases} \frac{f_i - c}{m} & \text{if } f_i = \underline{f} < f_S \\ \frac{f_i - c}{m+1} & \text{if } f_i = \underline{f} = f_S \\ 0 & \text{otherwise,} \end{cases} \quad (17)$$

where m denotes the number of issuers that charge \underline{f} . Similarly, the expected profit of the service provider from the same informed consumer is given as

$$\Pi_S^I(f_1, \dots, f_n; f_S) = \begin{cases} f_S - c & \text{if } f_S < \underline{f} \\ \frac{f_i - c}{m+1} & \text{if } f_S = \underline{f} \\ 0 & \text{otherwise.} \end{cases} \quad (18)$$

Next, we derive firms' expected profits from an uninformed consumer. The expected profit of issuer $i \in N$ from an uninformed consumer with willingness-to-pay weakly exceeding $E[f] = (\underline{f} + f_S)/2$ is given as

$$\Pi_i^U(f_1, \dots, f_n; f_S) = \begin{cases} \frac{f_i - c}{2m} & \text{if } f_i = \underline{f} \\ 0 & \text{otherwise.} \end{cases} \quad (19)$$

Similarly, the expected profit of the service provider from the same uninformed consumer is given as

$$\Pi_S^U(f_1, \dots, f_n; f_S) = \frac{f_S - c}{2}. \quad (20)$$

It is now easy to derive a firm's total expected profit. Given that informed demand is given by $D_I(\min(\underline{f}, f_S))$ and uninformed demand by $D_U(E[f])$, the expected profit of an arbitrary firm $i \in N_S$ may be written as

$$\begin{aligned} \Pi_i(f_1, \dots, f_n; f_S) &= \alpha D_I(\min(\underline{f}, f_S)) \Pi_i^I(f_1, \dots, f_n; f_S) \\ &\quad + (1 - \alpha) D_U(E[f]) \Pi_i^U(f_1, \dots, f_n; f_S). \end{aligned} \quad (21)$$

A.2 Existence of f_S^*

We claim that the service provider's objective function in problem (4),

$$\underline{\Pi}_S(f_S) = \frac{f_S - c}{2} \cdot D_U \left(\frac{f_S + c}{2} \right), \quad (22)$$

admits a maximum f_S^* in $[0, \infty)$. By Assumption 1(ii), we have $D_U(c) > 0$. Hence, by continuity, there exists $\varepsilon > 0$ such that $\underline{\Pi}_S(c + \varepsilon) > 0$. This shows that $\underline{\Pi}_S(f_S) < 0$ for $f_S \in [0, c)$, while $\underline{\Pi}_S(f_S) \geq 0$ for $f_S \in [c, \infty)$. Therefore, any maximum of $\underline{\Pi}_S$ must lie in the interval $[c, \infty)$. Since $\underline{\Pi}_S$ is continuous, it suffices to show that $\lim_{f_S \rightarrow \infty} \underline{\Pi}_S(f_S) = 0$. This, however, is obvious if $D_U(f_S) = 0$ at some finite $f_S > 0$. Otherwise, i.e., if $D_U(f_S) > 0$ for all $f_S \geq 0$, then logconcavity of D_U combined with $D'_U < 0$ implies that D_U is declining exponentially to zero as $f_S \rightarrow \infty$. Indeed, since $\ln D_U$ is strictly declining and concave, there exists an $L > 0$ such that $\ln D_U(f_S) \leq \ln D_U(0) - Lf_S$. Applying the exponential function on both sides of that inequality implies that $D_U(f_S) \leq D_U(0) \cdot \exp(-Lf_S)$, as has been claimed. This proves the assertion. \square

A.3 Uniqueness of f_S^*

We claim that $\underline{\Pi}_S(f_S)$ is strictly quasiconcave on the subinterval of $[c, \infty)$ where $D_U \left(\frac{f_S + c}{2} \right) > 0$. For this, consider a fee level $f_S > c$ satisfying $D_U \left(\frac{f_S + c}{2} \right) > 0$ as well as the first-order condition

$$\frac{1}{2} \cdot D_U + \frac{f_S - c}{4} \cdot D'_U = 0, \quad (23)$$

where we dropped the arguments. By a standard condition for strict quasiconcavity (Diewert et al., 1981), it suffices to show that

$$\underline{\Pi}_S''(f_S) = \frac{1}{2} \cdot D'_U + \frac{f_S - c}{8} \cdot D''_U < 0. \quad (24)$$

However, by Assumption 1, we have $D'_U \leq D'^2_U/D_U < 2D'^2_U/D_U$. Hence,

$$\underline{\Pi}''_S(f_S) < \frac{1}{2} \cdot D'_U + \frac{f_S - c}{4} \cdot \frac{D'^2_U}{D_U} \quad (25)$$

$$= \frac{D'_U}{D_U} \left(\frac{1}{2} \cdot D_U + \frac{f_S - c}{4} \cdot D'_U \right) \quad (26)$$

$$= 0. \quad (27)$$

Therefore, by continuity, the function $\underline{\Pi}_S$ defined through equation (22) is indeed strictly quasiconcave on the subinterval of $[c, \infty)$ where uninformed demand is positive.

A.4 Equilibrium property

Clearly, no issuer has an incentive to operate below marginal costs. Suppose that $f_i > c$ for some $i \in N$. Then, issuer i loses any business with the informed consumers. However, issuer i also loses any business with the uninformed consumers, because those can still discriminate among issuers. Thus, issuer i has no incentive to deviate. As for the service provider, a deviation to some price level $f_S \leq c$ is never optimal. Similarly, a deviation to some price level $f_S \in (c, f_S^*) \cup (f_S^*, \infty)$ strictly lowers the profit from the business with the uninformed because f^* optimizes equation (4), and does not attract any informed consumer because informed consumers know the state of the world and would select the lower fees offered by the issuers.

A.5 Equilibrium uniqueness

To provoke a contradiction, suppose that there is an equilibrium with fees f_1, \dots, f_n and f_S that differs from the equilibrium described in the proposition. Extending the standard uniqueness argument underlying Proposition 1, it is not feasible that $\underline{f} \neq c$ in equilibrium. Hence $\underline{f} = c$, and all issuers set their fees equal to c because

of their second-order preference for market share. But given that $f_1 = \dots = f_n = c$, this implies that $f_S = f_S^*$ must hold in equilibrium. This concludes the proof of equilibrium uniqueness, and thereby, of the proposition. \square

Proof of Proposition 3. When providing DCC as an option to potentially uninformed consumers, the service provider solves

$$f_S^* = \arg \max_{f \geq 0} \frac{f_S - c}{2} \cdot D_U \left(\frac{f_S + c}{2} \right), \quad (28)$$

with corresponding first-order condition

$$\frac{f_S^* - c}{2} \cdot D'_U \left(\frac{f_S^* + c}{2} \right) + D_U \left(\frac{f_S^* + c}{2} \right) = 0. \quad (29)$$

We convexify the two problems (4) and (5) by considering the hypothetical profit function

$$\Pi(f, q) = (f - c) \left(1 - \frac{q}{2} \right) D_U \left(\left(1 - \frac{q}{2} \right) f + \frac{q}{2} c \right), \quad (30)$$

where $q \in [0, 1]$. For $q = 0$, the function $\Pi(f, 0)$ represents the objective function of the monopoly, while for $q = 1$, the function $\Pi(f, 1)$ represents the objective function of the service provider when issuers price at marginal costs. For any $q \in [0, 1]$, the optimum is given by

$$f_q = \arg \max_{f \geq 0} \Pi(f, q), \quad (31)$$

and the corresponding first-order condition may be reduced to

$$(f_q - c) \left(1 - \frac{q}{2} \right) D'_U + D_U = 0, \quad (32)$$

where we dropped the arguments. We also note that $f_0 = f^M$ and $f_1 = f_S^*$. To prove the proposition, it therefore suffices to show that the cross-derivative of

$\Pi(f, q)$ is positive at f_q , for any $q \in [0, 1]$ (Milgrom and Shannon, 1994). This, however, can be checked in a straightforward way. Indeed, taking the cross-derivative of (30), evaluating at $f = f_q$, and finally exploiting the first-order condition (32) yields

$$\frac{\partial^2 \Pi(f, q)}{\partial q \partial f} \Big|_{f=f_q} = -\frac{f_q - c}{2} \left(1 - \frac{q}{2}\right) \left\{ 2D'_U + (f_q - c) \left(1 - \frac{q}{2}\right) D''_U \right\}. \quad (33)$$

However, from the necessary second-order condition (see the proof of Proposition 2),

$$\frac{\partial^2 \Pi(f, q)}{\partial f^2} \Big|_{f=f_q} = \left(1 - \frac{q}{2}\right)^2 \left\{ 2D'_U + (f_q - c) \left(1 - \frac{q}{2}\right) D''_U \right\} < 0. \quad (34)$$

Since, for obvious reasons, $f_q > c$, this proves the claim. \square

Proof of Proposition 4. As in the proof of Proposition 3, we consider the convexified problem

$$\Pi^*(q) \equiv \Pi(f_q, q) = \max_{f \geq 0} \Pi(f, q), \quad (35)$$

for $q \in [0, 1]$, where $\Pi(f, q)$ is defined by (30). Recall that, for $q = 0$ and $q = 1$, respectively, problem (35) corresponds to the problem of the monopolist and the service provider. A straightforward application of the envelope theorem delivers

$$\frac{\partial \Pi^*(q)}{\partial q} = \frac{\partial \Pi(f, q)}{\partial q} \Big|_{f=f_q} \quad (36)$$

$$= -\frac{f_q - c}{2} \left\{ D_U + \left(1 - \frac{q}{2}\right) (f_q - c) D'_U \right\}, \quad (37)$$

for any $q \in [0, 1]$. However, from the first-order condition,

$$\frac{\partial \Pi(f, q)}{\partial f} \Big|_{f=f_q} = \left(1 - \frac{q}{2}\right) \left\{ D_U + \left(1 - \frac{q}{2}\right) (f_q - c) D'_U \right\} = 0, \quad (38)$$

so that $\partial \Pi^*(q)/\partial q = 0$ for all $q \in [0, 1]$. The claim follows. \square

Details on Example 2. The isoelastic demand specification does not satisfy Assumption 1. Here, we briefly outline the changes needed to the proof of Proposition 2 to cover this case.⁴⁷ A first change concerns the proof of existence of f_S^* . Specifically, we need to check the boundary condition

$$\lim_{f_S \rightarrow \infty} \frac{f_S - c}{2} \cdot D_U \left(\frac{f_S + c}{2} \right) = 0. \quad (39)$$

It suffices to show that

$$\lim_{f \rightarrow \infty} f D_U(f) = 0. \quad (40)$$

Indeed, if (40) holds, then also $c D_U(f)$ tends to zero as $f \rightarrow \infty$, so that (39) holds true. But relationship (40) is obvious in the isoelastic case where $D_U(f) = f^{-\eta}$ with $\eta > 1$. Second, we need to check that the unboundedness of D_U at zero does not interfere with existence. But since $\underline{\Pi}_S < 0$ on the interval $(0, c)$, this is not a problem. Third, to obtain uniqueness of f_S^* , we need to check that the isoelastic specification satisfies $D_U'' D_U - 2D_U'^2 < 0$. This, however, can be readily verified since

$$D_U'' D_U - 2D_U'^2 = (\eta(\eta + 1) - 2\eta^2) D_U = -\eta(\eta - 1) D_U < 0. \quad (41)$$

With these changes in place, the proof goes through as before. \square

⁴⁷The proofs of the other results need no changes.

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Notation (not for publication)

$N = \{1, \dots, n\}$	set of issuers, where $n \geq 2$
$N_S = N \cup \{S\}$	set of competitors, with elements i, j
$f_i \geq 0$	fee set by competitor i
$c \geq 0$	marginal costs
$\mu \in \{H, F\}$	payment currency
$\gamma = (i, \mu), \gamma_0$	consumer choice, outside option
$\Omega = \{\omega_T, \omega_C\}$	state space
$\alpha \in [0, 1]$	the informed share of the population
D_I, D_U	informed and uninformed demand
$\underline{f} = \min\{f_1, \dots, f_n\}$	the lowest fee among the issuers
$\bar{E}[f]$	fee expected by uninformed consumers
f_S^*	equilibrium fee set by S
f^M	monopoly fee
$\underline{\Pi}_S$	expected profit of S from uninformed if $\underline{f} = c$
m	number of issuers that charge \underline{f}
Π_i^I, Π_i^U	i 's expected profit from informed (uninformed)
$\Pi_i(f_1, \dots, f_n; f_S)$	i 's expected profit
$\Pi(f, q)$	convexified profit function
$\Pi^*(q)$	maximum expected profit
$f^{\max}, D^{\max}, \gamma$	demand parameters in Example 1
$\eta > 1$	elasticity parameter in Example 2
k	number of service providers
$p_T \in [0, 1]$	prior probability of state ω_T
$P = \{p_T \in [0, 1]\}$	set of beliefs
λ	costs of information acquisition
f_S^λ	optimal fee for the service provider
$\varepsilon > 0$	small positive number
L	slope parameter