Do sellers adjust prices to be paid cash?

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Abstract

Sellers bear an important share of transaction costs, especially of payments costs. They vary with the payment instrument, and are therefore impacted by the choice of the buyer. Sellers are interested in steering the choice towards the payment instrument they judge less costly. We analyse a strategy consisting in setting prices that involve few notes and coins so that paying them cash is easier. Such prices are reffered to as convenient. We develop a theoretical model and formulate two propositions: the more convenient the price (i) the more often a seller sets it (ii) the more often a buyers pays it cash. We use hand collected data to provide empirical evidence consistent with the theoretical results.

Key Words: Convenient prices, Price distribution, Payment instruments.
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1 Introduction

Frictionless markets are rare, if not inexistent outside financial markets. Transaction costs, and in particular payment costs always reduce both seller and buyer surpluses, sometimes to the point that the transaction is not made at all.

Since payments costs, mostly borne by sellers, vary with the payment instrument that buyers choose, and since most countries forbid setting different prices for different payment instruments ("no surcharge rule"), steering buyer's choice towards the payment instrument judged less costly is an issue. Cash has no direct monetary cost as opposed to bank card, the main alternative in share of transactions. Indirect costs, for instance storage costs and risks of loss or theft are often underestimated (Hanneman, 1991, Robinson and Hammitt, 2011). Cash is therefore widely perceived as the less costly payment instrument (Bearing point, 2009).

Sellers, however, have limited options to achieve this aim. They can refuse *a priori* alternative payment instruments, but the decision is sunk when an individual transaction occurs, and this degrades the seller's perceived quality, reducing demand (cf Rochet and Tirole, 2007). Some prices are more easily paid cash. For instance, 10 and 9.99 euros are respectively more convenient than 7.73 and 17 euros. 9.99 euros is more convenient than 17 euros, because the former involves more notes and coins -referred to as "tokens" from now on-than the latter (either buyer pay the full sum directly or the sellers returns change). We define "objective convenience" the minimal number of tokens exchanged between buyer and seller, whether the buyer pays the full sum directly or the merchant returns change. We call n-convenient prices having an objective convenience of n. Objective convenience is also defined this way in Knotek (2011) and referred to there as relative inconvenience.

Convenient prices significantly reduce cognitive costs to the buyer (the mental operation of dividing the price in tokens), the inconvenience of carrying numerous tokens (Lee, 2009) and expedite the payment faster (Knotek, 2011). Therefore, setting a convenient price may be an incentive for consumer to pay cash. Since , however, our model is aimed at studying how convenience effects impacts price setting and the prevalence of cash payments, we need to introduce *the monetary equivalent of convenience costs borne by buyers*. This is because only buyers decide the payment instrument at a card accepting seller's shop. We call this monetary equivalent *the subjective convenience*. For all the results of our theoretical model to hold, we need only three assumptions on subjective convenience. We assume that the function associating objective to subjective convenience *is strictly increasing* and that *the marginal token is more costly*. We also assume that a price pair sharing the same objective convenience has subjective convenience in the same order as itself. Our first result is that the probabilities of price setting are ordered in the same sense as objective conveniences, for prices with positive probabilities to be set. Our second result is that a buyer is more likely to pay cash a price with a lower objective convenience (the two prices considered are still with positive probabilities to be set).

We also collected 411 prices paid with cash or with card to provide consistent empirical evidence to our theoretical results (since we study the impact of convenience on the relative costs compared to all alternatives we retained only cash and card as payment instruments). We retained multiple markets instead of a single market like in the theoretical model, but it is a convincing microfoundation to our empirical results. We find that in the data, buyers pay more frequently cash a price with a lower objective convenience, and that seller set such a price more frequently.

We contribute to the literature at the theoretical, methodological and empirical levels. Theoretically, we do not know of any model analysing the impact of convenience effects on price setting. We solve a two stage, two player sequential game and derive two propositions: A price with a low objective convenience- involving few tokens exchanged- is set more frequently by the seller (1) and is more paid cash by the buyer (2). Methodologically, we propose a simple algorithm to compute the objective convenience of a price. This algorithm can be applied to different problems (cf conclusion). More importantly, our result shed a different light on other remarkable prices discussed by the literature, namely round and odd prices. A round price is a multiple of 5 euros, or a small fraction like 50 cents. An odd price is one token below a round price (you can get a round price from an odd price by adding a small facial value coin. Those prices are said to be "psychologically attractive". They are both locally minimising the number of tokens involved in a cash transaction (they are *convenience points*). Therefore, our results suggest that they are set also because sellers want a higher share of sales to be paid cash. Research on that specific topic may be fruitful, and research on the reasons of round and odd prices setting may find it friutful to at least control for the cash motive.

Empirically, we provide consistent evidence that a price involving only a few tokens is set more frequently and is more frequently paid cash *Ceteris Paribus*. We also provide evidence of the transaction size effect (a higher price is less frequently paid cash). A seller preferring to be paid cash has an incentive to set convenience points. Therefore, our results can be a complementary explanation for price stickiness. Sticky prices are important for the analysis of monetary policy and for the analysis of business model fluctuations (Clarida *et al.* , 2001, Erceg *et al.*, 2000 as well as Carlton, 1986 , and Levy *et al.*, 1997 are only a few examples, respectively for the analysis of short and long term price stickiness.) Knotek (2011) notices that objective convenience effects provide a complementary explanation to price stickiness. However, a model based on subjective convenience can replicate a much larger set of price stickiness distributions. Recall that we impose no functional form to the function associating objective to subjective convenience. We only need three simple and natural assumptions. While objective convenience can take a very limited set of values, subjective convenience can theoretically take as many values as the number of prices considered.

2 A measure of convenience

The situation in which the buyer pays the full sum directly and the situation in which the seller returns change involve different minimal numbers of tokens exchanged between buyer and seller. The number of steps of each of the two algorithms we now describe corresponds to the minimal number of notes and coins corresponding to each situation.
Define den=$\{0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100, 200, 500\}$ the set of facial values of Euro tokens.

2.1 The objective convenience function

A price paid cash involves a minimum number of tokens exchanged between buyer and seller. We allow for the possibility that the merchant returns change (for instance, a price 9.50 euros involves no less than 2 tokens, corresponding to the buyer handing a 10 euros note, and the seller returning 50 cent). The function giving the minimum number of tokens exchanged when a price is paid cash is the objective convenience function.

The direct greedy algorithm

Each step of this algorithm represents a token handed by the buyer to pay the exact sum asked by the seller. The buyers gives the highest token whose facial value is inferior to the price, then the highest facial value inferior to the residual price, and the process continues until the whole price is paid .

The indirect greedy algorithm

The first step of this algorithm represents the initial token handed by the buyers, the following steps correspond to the change returned. The buyer hands the lowest note or coin superior to the price, then the seller returns change by applying the direct greedy algorithm to the difference between the token handed and the price.

We note $DG(p)$, $DG : \mathbb{R}^+ \to \mathbb{N}^+$ and $IG(p)$, $IG : \mathbb{R}^+ \to \mathbb{N}^+$ the number of steps respectively of the direct and indirect greedy algorithms, we note $OC(p)$, $OC\mathbb{R}^+ \to \mathbb{N}^+$ the minimal number of steps of these two algorithms, $OC(p) = \min\{DG(p);IG(p)\}$ $OC : \mathbb{R}^+ \to \mathbb{N}^+$. We call $OC(p)$ the objective convenience function. Let S be the set of accesible prices, in a sense we precise in the next section.

Define $Cl(p), Cl : \mathbb{R}^+ \to \mathscr{P}(S)$, where $\mathscr{P}(S)$ is the power set of S. A price p is said to be n-convenient if $OC(p) = n$. If p is n-convenient, $Cl(p)$ is the set of n-convenient prices $Cl : \mathbb{R}^+ \to \mathscr{P}(S)$ and $Cl(p) = \{z \in S, OC(z) = OC(p)\}$. Cl_i is the set of i-convenient prices, $Cl_i = \{z \in S, OC(z) = i\}$.

2.2 The subjective convenience function

The monetary equivalent of the penibility of decomposing price p in tokens (*cognitive cost*), handing them to the seller, and carrying the change if returned is the subjective convenience function $SC(p)$, $SC : \mathbb{R}^+ \to \mathbb{R}^+$.

SC is strictly increasing in $OC(p)$. The marginal token is more costly. Formally, if we note $SC_I = SC(p_I)$, $OC_I = OC(p_I)$, $\forall (p_A, p_B, p_C) \in S^3(p)$,

$$OC_A > OC_B \implies SC_A > SC_B, \tag{1a}$$

$$OC_A > OC_B > OC_C \implies SC_C - SC_B > SC_B - SC_A. \tag{1b}$$

$$OC_A = OC(B), p_A > p_B \implies SC_A \geq SC_B \tag{1c}$$

Assumption 1c implies that a buyer desire less prices involving many small coins than prices involving notes, since the former prices are typically lower than the latter.

Define $C = SC(p \backslash Cl(p) = Cl_2) - SC(p \backslash Cl(p) = Cl_1)$. C is the monetary difference between the convenience of paying cash a 2-convenient and a 1-convenient price. C is the minimum marginal convenience effect from equation 1b.

$$C > \frac{\overline{p}\overline{b}}{\frac{\underline{\gamma}+\overline{\gamma}}{2}} = \frac{\overline{p}\overline{b}}{E(\gamma)} = 2\overline{p}\overline{b} \tag{2}$$

In the remainder of the paper convenience without precision refers to objective convenience. Equation 2 states that convenience costs are important enough relative to market power and to net benefits for cash payments.

3 The model

Two complementary interpretations of the model are possible. First, we can consider two continua respectively of heterogenous merchants and consumer, each individual being characterized by a parameter. Second, we can consider a single seller and a single buyer, each drawing relevant parameters on uniform distributions. The former and latter interpretation yield respectively frequential and probabilistic results. The following exposition of the two stage sequential game involves two players, a seller and a buyer, since this presentation is more concise. We leave the formulation of the equivalent frequential results and assumptions to the care of the reader.

3.1 The seller

We study a strategy of price adjustment, therefore a seller can not face perfect competition and must be *price maker*. The more market power she'll have, the more she'll be able to depart from the marginal cost.

We consider a seller whose production cost is normalised at zero. She has market power and sets her price $p \in S$. S is a compact set with a null lower bound and a upper bound $\overline{p}$, $S = [0, \overline{p}]$. For a seller in a competitive market (deprived of market power), $\overline{p} = 0$, and $S = 0$.

If the good is paid cash, the relevant marginal costs are that of cash management and denoted $\alpha \in \mathbb{R}^+$. They comprise cost in time associated with sorting tokens as well as moving them to the banks, plus the costs of storage and the risks of loss and theft. They also comprise the cognitive cost associated with the decomposition of price in tokens. If the good is paid with card, the relevant marginal costs are the direct transaction costs, and are denoted $\beta \in \mathbb{R}^+$. They represent the cost of buying a terminal plus the payment to the card network.

α and β are drawn from two uniform distributions, $\alpha \in [\underline{\alpha}; \overline{\alpha}]$ and $[\underline{\beta}; \overline{\beta}]$. Therefore, the seller draws her perceived cash management cost net of the card equivalent $\gamma \in [\underline{\alpha} - \overline{\beta}; \overline{\alpha} - \underline{\beta}] = [\underline{\gamma}; \overline{\gamma}], \overline{\gamma} - \underline{\gamma} = 1$. γ is drawn from a uniform distribution, since it is the difference of two uniform variables. We assume that $\overline{\gamma} - \underline{\gamma} = 1$ without loss of generality.

We note $\gamma = \alpha - \beta$ the seller's algebric marginal relative preference for cash. A seller with $\gamma > 0$ perceives the card payment cost as greater than the costs of cash management. γ is the marginal cost (in currency units) of a card payment net of marginal payment cost of a cash payment.

3.2 The buyer

Price adjustment for convenience reasons does not exclude buyers and the buying decision is taken ex-ante. The demand for the good is constant for $p \in]0; \overline{p}[$ and null for $p \geq \overline{p}$. Buyers choose between paying cash and generic payment instrument- identified with bank card. The benefits of cash payments regardless of convenience costs are denoted $b_{cash} \in \mathbb{R}^+$. If the good is paid with bank card, the benefits of card payments are denoted $b_{card} \in \mathbb{R}^+$.$b_{card}$ represents the cost of buying a terminal plus the payment to the card network. b_{cash} and b_{card} are drawn from uniform distributions, $b_{cash} \in [\underline{b_{cash}}; \overline{b_{cash}}]$ and $b_{card} \in [\underline{b_{card}}; \overline{b_{card}}]$

A buyer decides to pay with cash or with card and draws his net benefit for paying cash regardless of convenience effects $b = b_{cash} - b_{card}$, $b \in [\underline{b_{cash}} - \underline{b_{card}}; \overline{b_{cash}} - \overline{b_{card}}] = [\underline{b}; \overline{b}]$, $\overline{b} - \underline{b} = 1$. At least a single buyer prefers cash payments ($\overline{b} > 0$) and b is drawn from a uniform distribution since it is the difference of two random uniform variables.

Resolution

Sellers play before buyers and we solve the game by backwards induction.

Turn of the buyer

The buyer maximise the paying utility by choosing either to pay cash or to pay with card, given his relative preference for cash b and the price p. He pays cash if $b - SC(p) \geq 0$ and then his paying utility $U(.)$ is $(b - SC(p))$. He pays with card if $b - SC(p) < 0$ and then his paying utility is $-b > 0$. Cash is the default payment instrument, a buyer indifferent between payment instruments pays cash.

$$\max_{i \in \{Cash, Card\}} U(i) = (b - SC(p))\mathbb{1}_{\{b - SC(p) \geq 0\}} - b\mathbb{1}_{\{(b - SC(p)) < 0\}}$$

.

Let $MP_{card+cash}$, MP_{cash}, and MP_{card} the mass of payment total (card and cash), cash and card. We have

$$MP_{card+cash} = \int_{\underline{b}}^{\overline{b}} du, \quad MP_{card} = \int_{\underline{b}}^{C(p)} du, \quad MP_{cash} = \int_{C(p)}^{\overline{b}} du. \tag{3}$$

Turn of the seller

The program of the seller i is

$$\max_{p \in S} \pi(p)$$

The unit margin is p if the buyer pays cash and $p - \gamma$ if the buyer pays with card. Therefore, we have

$$\pi(p) = (p-\gamma)\int_{\underline{b}}^{SC(p)} du \ + p\int_{SC(p)}^{\overline{b}} du$$
$$= (p-\gamma)(SC(p)-\underline{b}) + p(\overline{b}-SC(p))$$
$$= p(\overline{b}-\underline{b}) - \gamma(SC(p)-\underline{b})$$

LEMMA 1

Let p_0 be the profit maximising price if $SC(p)$ is identically null. Let $F(p_0) = \bigcup_{i=1}^{OC(p_0)} \max_{p\in Cl_i} p$. We have

$$p^* = \arg\max_{p\in S} \pi(p) = \arg\max_{p\in F(p_0)} \pi(p)$$

The profit maximising price p^* is the highest price in one convenience class Cl_i. Lemma 1 states that a seller with enough market power sets a price of 10.60 euros rather than a price of 10.40 euros, since $OC(10.60) = 3 = OC(10.40)$ and $10.60 > 10.40$.

Proof. The proof is in the appendix. ■

Assume that p_0 is k convenient. There are at most $k = Card(F(p_0))$ prices with a positive probability to be set. A price not the highest in its convenient class is not set, $Pr(p \notin F(p)) = 0$ (in particular $Pr(p_0) = 0$). We refer to prices with a positive probability to be set as candidate prices. They are strictly ordered regarding convenience.

LEMMA 2

$$p^* \in J(p_0) = \bigcap_{\varepsilon\in\mathbb{R}^+,\phi\in\mathbb{R}^+} J_{\varepsilon,\phi}$$

$$J_{\varepsilon,\phi} = \{[p_0-\varepsilon; p_0+\phi], \forall i \in [\![1, OC(p_0)]\!], \exists p_i \in [p_0-\varepsilon; p_0+\phi],\ OC(p_i) = i\}$$

If we note p_i^{max} the highest i-convenient price, lemma 2 states that the profit maximising price is in an interval containing p_0 with lower bound $\underline{p} = \min_i p_i^{max}$ and upper bound $\max\{\max_i p_i^{max}; (p_0\}$.

Proof. The proof is in the appendix. ■

A consequence of Lemma 2 is that the assumption that the demand is constant over $J(p_0)$ is equivalent to the assumption that demand for the good is constant for $p \in [0; \underline{p}]$.

Alternatively, the assumption that demand is inelastic for $p \in]0; \underline{p}[$ and constant for $p \in J(\underline{p})$ is also equivalent.

PROPOSITION 1 *Let $Pr(p)$ be the probability that the seller sets a price p. If $(p_A, p_B) \in F(p)^2, OC(p_A) > OC(p_B)$, then $Pr(p_B) > Pr(p_A)$.*

A more convenient candidate price is more likely to be set except for p_0. If $p_i = \max_{p \in Cl_i} p$ and $i > j, i \neq 0$, then $Pr(p_j) > Pr(p_i)$.

Proof. The proof is in the appendix. ■

The share of sellers setting a price of 10 euros is more important than the share of seller setting a price of 10.27 euros, because $OC(10) = 1 < OC(10.2) = 3$. The share of sellers setting a price of 10.27 is less important than the share of sellers setting a price of 10.20 euros, because $OC(10.27) = 4 > OC(10.20) = 3$.

We note $Pr(p, cash)$ the probability that the buyer pays price p cash,

PROPOSITION 2 *Let $Pr(p, cash)$ be the probability that the buyer pays cash price p. If $OC(p_A) > OC(p_B)$, then $Pr(p_B, cash) > Pr(p_A, cash)$.*

The more convenient a price, the higher the probability buyers pay cash.

Proof. The proof is in the appendix. ■

Prices involving less tokens are more paid cash. The share of cash paying buyer for a price of 10 euros is more important than for a price of 10.27 euros, because $OC(10) = 1 < OC(10.2) = 3$. The share of cash paying buyers for a price of 10.27 is less important than for a price of 10.20 euros, because $OC(10.27) = 4 > OC(10.20) = 3$.

In particular, convenience has more often than not an effect on price setting (since convenience effect increases cash paying cost while leaving unchanged the cost of other payment instruments).

4 Data

Table 1: Transaction characteristics

	(1)	(2)	(3)
Indirect greedy	9	4.19	1.69
Greedy	9	4.4	1.7
Convenience	7	3.4	1.2
Cash	1	47.9%	0.5
Card	1	52.1%	0.5
Number cash	4	0.7	0.9
Number card	1	52.1	0.5
Number	4	1.2	0.6

Notes Column (1), (2) and (3) gives respectively the maximum , mean and median value of variables. Indirect greedy gives the minimum number of tokens exchanged, imposing that the seller returns change. Greedy gives the maximum number of tokens exchanged, imposing that the buyer pays the full sum directly. Cash and card are dummies for transaction paid respectively cash and with card. Number cash and card are respectively the number of transactions paid cash and with card at a given price. Number is the number of transaction paid at the prices. We did not give minima, since they are not informative here.

The dataset comes from a field inquiry. We took down the price paid abd the payment instrument used for 411 purchases of a single product since sellers have better control of the price paid. The purchases were paid cash or by card.

Table 1 gives transaction characteristics. A bit less than half of the transactions are paid cash. Prices involve no more than 8 tokens for their cash payments (no more than 12 tokens if they're paid directly, and no more than 10 tokens if merchants return change). At most four transactions are paid cash at the same price, at most three are paid with card at the same price. Buyer pay the same price 1.3 times in average. Prices range from 0.57 to 480 euros.

5 Empirical results

Table 2: Independence tests

(1)	(2)	(3)	(4)
Objective convenience/ Number of transactions			
75.6	-0.27	31.3	-9566
(0.000)	(0.000)	(0.000)	(0.000)
Objective convenience / cash payments			
46.2	-0.32	46.1	-14790
(0.000)	(0.000)	(0.000)	(0.000)

Notes Degrees of freedom are in parenthesis next to statistics. P-values are in parenthesis below the coefficients. Column (1) gives the Chi2, column (2) gives the linear correlation, column (3) gives Kruskal-Wallis statistics and column (4) gives Kendall's score. P-Values are given below the statistics. Chi-2 respectly have 18 and 6 degrees of freedom for the first and second pairs. Kruskal-Wallis respectively have 7 and 6 degrees of freedom.

We study two pairs of variables. The first pair is "objective price convenience", $OC(p)$ and "number of price occurrences". The second pair of variables is $OC(p)$ and "number of cash paid transactions".

For both pairs, we test the statistical independence with chi-squared. We also perform Kruskal-Wallis as well as Kendall's tau tests to determine the direction of the potential relations. Both tests are non parametric, and normality assumptions are not needed. Kruskal-Wallis assumes that distributions of populations have broadly the same shape, which is verified. Kendall's tau test only assumes that the dependent and independent variables are ordered, which is obvious for both pairs. Kendall's tau and Kruskal-Wallis test for two different notions of independence.

Indeed, the null of Kruskal-Wallis test is that the samples come from populations such that a random observation from one group is as likely to be lesser or greater than a random observation from another group. Kendall's tau is a measure of the strength of association between variables, in the sense that it is higher when observations pairs are ordered in the same way (*concordant pairs*. The null is the probability that there are as many concordant as discordant pairs. In other words, Kendall tau is a rank correlation test while Kruskal-Wallis is immediately interpreted in terms of probability.

Eventually, I tested the significance of the linear correlation for both pairs. The results are shown in table 2 and discussed in the two next subsections.

5.1 Are convenient prices more frequent in the price distribution?

All tests performed reject the null of independence between convenience and the number of transactions at a particular price. Kendall tau's score points out a positive relation between these two variables. This is confirmed by the sign and significance of the linear correlation. We verify Proposition 1: the more convenient a price, the more likely the seller sets it. We can, however, complement this result. The number of transactions at a particular price, noted n, is determined by a latent variable n^*. In other words, if we note T_i the threshold relative to $n*$, with the convention that $\overline{T}_i = \underline{T}_{i+1},\ i \in i \in [\![1,\ \max_{k \in S} OC(k) - 1]\!]$ we have:

$$Prob(n = i) = P(\underline{T}_i \leq n^* \leq \overline{T}_{i+1})$$

where :

$$n^* = F(a_1\ log(p) + a_2\ OC(p) + \varepsilon),$$

We assume that F(.) follows approximately a normal distribution and estimate an ordered probit. Higher value purchases are less frequent if only because a lesser number of buyers have a high enough disposable income to make the purchase. We expect a_1 to be negative.

Proposition 1 implies that a seller sets more a frequently a price with a lower objective convenience. Prices involving lesser notes or coins should therefore be more frequent, by agregation. We also expect a_2 to be negative.

Only 8.1 % of prices are repeated at least once, however. This is an unfortunate limitation of the database. The statistical significance of a modal variable like objective convenience may turn out to be difficult to achieve. Results are given in table 3.

Table 3: Ordered probit: number of transactions at a given price

Variable	(1)
Objective Convenience (*OC*)	-0.1[d]
	(0.11)
Transaction size (logarithm)	-0.46 [a]
	(0.10)
LR Chi-2 (2 degrees of freedom)	38.46 [a]
	(0.000)
Pseudo-R^2	0.1553
N	373

Notes. [a] ($p<0.001$), [b] ($p<0.01$) , [c] ($p<0.05$), [d] ($p \geq 0.05$). Standard errors are given below the coefficients. The P-value is given below the Chi-2. We merged the transactions paid with the same payment instrument at the same price. Taking the logarithm of price enhances significantly likelihood ratio statistic.

As expected, we can not reject the null of nullity of the coefficient of objective convenience. It is negative, however, as the model predicts.

Economic interpretation of ordered probit coefficients is uneasy, and not intuitive. Unfortunately, calculating numerical elasticities is impossible here, since n takes 4 modalities (a price is paid 1,2,3 or 4 times) and our model has less dependent variables.

We failed to back up independence tests results by ordered probit estimation, but of course this is not the same as establishing the opposite. There remains that the higher frequency of prices involving lesser tokens is still backed up by two other statistical techniques.

5.2 Are convenient prices more often paid cash rather than with another payment instrument?

5.2.1 Independence tests

All test reject the null of independence. Kendall Tau's score points out a positive relation between price convenience and the probability of paying cash. This is confirmed by the fact that Pearson's correlation is positive and significant. In other words, we verify Proposition 2 the less tokens are exchanged, the more likely the price is paid cash.

Whitesell(1989) assumes that the buyer chooses between paying cash and with an alternative payment instrument.

Since using the alternative payment has a fixed cost (which could be identified with a subscription fee), while cash usage has a cost proportional to the transaction size (i.e. the value of foregone interests), all transactions below a certain threshold are paid cash, while all others are paid with card.

Whitesell's model implies a threshold transaction size above which all transactions are paid with card and below which all transactions are paid cash. This is not true for real world transactions, but many empirical studies point out a negative correlation between transaction size and the probability of cash payments (Mot and Cramer, 1992; Klee, 2008). The data is consistent with that point: transaction sizes are sorted in ten classes, and table 4 gives the probability of cash payment for each. This probability decreases when transaction sizes increases. Moreover, there is a significant negative correlation between transaction size and the frequency of cash payments (cf table 4).

In other words, cash payments are less frequent when prices are high. This, however, can be accounted for either by a size effect or because convenient prices are less frequent with higher price. Therefore, we control for the size effect to isolate convenience effects.

Table 4: The transaction size effect on payment instrument choice.

Correlation Between transaction size and cash payments (P-Value): -0.22 (0.000)										
Transaction size class	1	2	3	4	5	6	7	8	9	10
Upper border price for class	4	7.95	10.95	16.15	21.87	29.4	39.98	56.07	86.81	480
Proportion of cash payments	87%	78%	54%	47%	44 %	29 %	18%	22%	22%	24%

Note Each class represents 10 % of the total number of prices. Classes are ordered in the sense that the highest price of class i is just inferior to the lowest price of class i+1. 92.23% of prices are less than 100 euros, the minimum price is 0.57 euro.

This can be achieved by estimating a regression with either the number of cash transactions as independent variable, one observation corresponding to a price (ordered probit model) or a regression in which the independent variable is a dummy for cash payments, one observation corresponding to a transaction (classic probit model).

We estimate first an ordered probit (the details are given in section **??**. The distribution of the latent variable n^* is

$$n^* = F(d_1\ log(p) + d_2\ OC(p) + \varepsilon),$$

We assume that F follows approximately a normal distribution and estimate an ordered probit. We expect d_1 to be negative, since we observe a decreasing trend in the probability of cash payments when prices are higher (cf table 4).

Proposition 2 of our model implies that prices involving lesser tokens are more often paid cash for a single market. A price involving less tokens should be more

Table 5: Ordered and binary probit models: Number of cash transactions explained by convenience and transaction size

Variable	(1)	(2)	(3)	(4)	(5)
Objective Convenience	-0.14[a]	-0.15[b]	-0.06[b]	-0.06[b]	-0.01[b]
	(0.06)	(0.06)	(0.02)	(0.02)	(0.03)
Transaction size (logarithm)	-0.44 [a]	-0.52[a]	-0.2[a]	-0.2[a]	-0.03[b]
	(0.06)	(0.07)	(0.03)	(0.03)	(0.01)
LRChi-2 (2 degrees of freedom)	90.47 [a]	111.81 [a]			
	(0.000)	(0.000)			
Pseudo-R^2	0.1293	0.1965			
N	373	411			

Notes. [a] (p<0.001), [b] (p<0.01) , [c] (p<0.05). Standard errors are given below the coefficients for ordered probits. The P-value is given below the Chi-2. We merged the transactions paid with the same payment instrument at the same price. Taking the logarithm of price enhances significantly the chi-squared. Column (1) gives the ordered probit estimation, column (2) gives the classic probit estimation. Column (3), (4), and (5) gives respectively the elasticities calculated from the binary probit for the independent variables at their mean, their median, or zero. A price paid twice cash corresponds to one observation for the ordered probit model (dependent variable is 2), and to two observations for the classic probit (dependent variable is 1 for each).

frequently paid cash, by agregation. We also expect d_2 to be negative.

We assume that F(.) follows approximately a normal distribution. We first estimate an ordered probit. Results are given in table 5.

The econometric model fits the data well. Global adjustment statistics are satisfying: the pseudo R-Squared is 0.13, and the Chi-squared with 2 degrees of freedom is extremely high. The estimation confirms the transaction size effect, since the associated coefficient is highly significant and negative. The convenience effect is also confirmed since the associated coefficients are also highly significant and negative.

Coefficients of ordered probits, however, are difficult to interpret. We can not calculate elasticities with this specification, since there are five possible numbers of cash transactions, and since our econometric model comprise two independent variables. Therefore, we decided to estimate a classic probit. The dependent variable is now the probability of cash payments. The results of the estimation are in line with those of the ordered probit, since both the coefficients of objective convenience and of transaction size are significant and negative. We calculated numerically elasticities at three points: independent variables are zero, independent variables are at their mean and independent variables are at their median.

At the median point, an increase of the objective convenience by 1% provokes a decrease of 0.06% in the probability of cash payments.

Proposition 1 and 2 receive empirical confirmation: prices are more frequent when they are more convenient, and more convenient prices are more often paid cash.

6 Conclusion

We examine whether sellers set convenient prices, involving few tokens to be paid, to make buyers pay cash and whether this strategy is a success. We develop a theoretical model and use an original dataset coming from a field inquiry to this aim.

In the model, a seller bears different costs for cash and card payments. We show that the less tokens involved for paying a price (i) the higher the probability a seller sets it and (ii) the higher, the probability a buyer pays it cash.

We took down price and payment instrument used for 411 transactions taking place in three stores with market power to gather data and provide empirical evidence consistent with the theory.

We measure objective convenience as the minimal number of tokens exchanged between buyer and seller, whether the price is paid in full directly or the sellers gives the change. We evidence both a significant negative rank and probability correlation between convenience and the number of transactions for a particular price. We also evidence both significant negative rank and probability correlation between convenience and cash payment frequency.

Since high prices are more often paid cash, convenience and transaction size effects both participate to the decision of paying cash. Therefore, an estimation of the convenience effect must control for the size effect. We estimate an ordered probit in which the dependent variable is the number of transactions effected for a particular price, and in which dependent variables are convenience and size effects. The estimation confirms a significant and negative transaction size effect, and a negative convenience effect on the frequency of cash payments. The latter impact is unfortunately not statistically significant.

We conclude that empirical evidence is consistent with sellers adjusting their prices in order to induce cash payments, and buyers paying convenient prices more often with cash than with alternative payment instruments. Both propositions derived from the model are empirically validated.

Our study provides ground to take special care of controlling the convenience effect while studying the efficiency and prevalence of other remarkable prices like odd and round prices. Our research suggest that the impact of convenience on payment instrument choice may concern a much larger set of prices than is conventionnaly believed, since we show that they may be set because sellers want to be paid cash. Further research on the relations between those prices and their impact on buyer demand is needed.

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Appendix

Proof of lemma 1. We first show a lemma useful for the demonstration.

SUBLEMMA 1
In each convenience class, the proxit maximising price is the highest.

$$\arg\max_{p\in Cl(p)} \pi(k) = \max_{p\in Cl(p)} p = p_m$$

Proof of sublemma 1.
Reductio ad absurdum. Assume $p' \neq p_m, \quad OC(p') = OC(p_m),\ \pi(p') > \pi(p_m)$.

$$p'\overline{b} - \gamma_i SC(p') > p_m\overline{b} - \gamma_i SC(p_m)$$

Since $0C(p_m) = OC(p')$, this implies $p' > p_m$ with equation 1c, a contradiction. ■

The proof of lemma 1 is immediate using sublemma 1 and considering that S is the reunion of convenience classes, $S = \bigcup_{i\in[\![1,\max\{OC(k),k\in S\}]\!]} Cl_i$. ■

Proof of lemma 2. The proof is immediate considering the theorem and $(F(\overline{p}) \cup \overline{p}) \subset J$. ■

Proof of Proposition 1. Assume $(p_A, p_B) \in (F(p) \cup p_0)^2, OC(p_B) > OC(p_A)$, ($p_B$ is less convenient than p_A). We note $SC(p_B) = SC_B$ and $SC(p_A) = SC_A$. If $p_A > p_B$ then both convenience and direct effect lead to setting p_A and there is nothing to show. If $p_B > p_A$, the following inequations are equivalent

$$\pi(p_A) - \pi(p_B) = (p_A - p_B)(\overline{b} - \underline{b}) + \gamma(SC_B - SC_A) > 0$$

$$(p_A - p_B)(\overline{b} - \underline{b}) > \gamma(SC_A - SC_B)$$

$SC_B > SCA$ (cf (1a)), therefore

$$\pi(p_A) - \pi(p_B) > 0 \Leftrightarrow \gamma < (\overline{b} - \underline{b}) * \frac{p_A - p_B}{SC_B - SC_A} = \lambda.$$

If we note $\gamma(p)$ the set of γ for which the seller sets p_A rather than p_b and $Pr(p_{A>B})$ the probability than the seller prefers p_A over p_B.

$$Pr(p_{A>B}) = \frac{\int_{\gamma(p_A)} du}{\int_{\underline{\gamma}}^{\overline{\gamma}} du} = \frac{\int_{\underline{\gamma}}^{\lambda} du}{1} = \lambda - \underline{\gamma}$$

$$Pr(p_{B>A}) = \frac{\int_{\gamma(p_B)} du}{\int_{\underline{\gamma}}^{\overline{\gamma}} du} = \frac{\int_{\lambda}^{\overline{\gamma}} du}{1} = \overline{\gamma} - \lambda$$

If we note

$$Pr(p_{A>B}) - Pr(p_{B>A}) = \int_{\gamma(p_A)\setminus\gamma(p_B)} = \overline{\gamma} + \underline{\gamma} - 2\lambda$$

$SC_B - SC_A < SC(p\setminus OC(p) = 2) - SC(p\setminus OC(p) = 1)$ from equation (1b). Eventually, $\int_{\gamma(p_A)\setminus\gamma(p_B)} du > 0$ from equation (2).

■

Proof of Proposition 2. A buyer maximise utility by choosing either to pay cash or to pay with card, given their relative preference for cash b and the price p. The program is

$$\max_{i\in\{Cash,Card\}} U(i) = (b - SC(p))\mathbb{1}_{\{b-SC(p)>0\}} - b\mathbb{1}_{\{(b-SC(p))\leq 0\}}$$

.

Therefore, $Pr(p, cash) = Pr(b > SC(p)) = SC(p) - b$ and together with equation 1a , $OC(p_A) > OC(p_B), Pr(p_A, cash) > Pr(p_B, cash)$. Sellers are more likely to set more convenient price, and in particular $Pr(p_0) = 0$ if $p_0 \notin F(p_0)$. ■