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Interest Rates, Product Prices and Trade Credit Terms

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Abstract

Empirical studies document that the full effect of monetary policy is not passed through to trade credit terms or product prices. We illustrate this numerically in a partial equilibrium model of third-degree price discrimination. Our computations show that trade credit terms and product prices are stable even with large changes in macroeconomic interest rates. When menu costs are considered, we find that the increase in NPV from optimizing trade credit terms and product prices is less than even miniscule menu costs for short-term interest rate changes in low-inflation periods. Therefore, the Meltzer (1960) effect holds and trade credit terms and product prices remain unchanged. However, in high inflation periods when nominal interest rates exceed a certain threshold, it becomes optimal for firms to change the terms of credit and product prices. Finally, we discuss exchange rate pass-throughs and the effectiveness of monetary easing in a pandemic.

Keywords: Working Capital, Product Pricing, Monetary Policy

1. Introduction

How does trade credit affect the credit channel of monetary policy transmission? This interest in monetary policy effectiveness has increased in recent years. However, there has not been a satisfactory theoretical model to explain the empirical stylized fact that trade credit dampens the impact of central bank actions. In this paper, we present a partial equilibrium model of third-degree price discrimination with menu costs. The main result is that the increase in NPV from optimizing credit terms and product prices is less than even miniscule menu costs for short-term interest rate changes in low-inflation periods. Therefore, credit terms and product prices are stable over time. This finding is consistent with Ng, Smith and Smith's (1999) and Mateut's (2005) empirical evidence and may also explain the Meltzer (1960) hypothesis on credit channel transmission of monetary policy, i.e., trade credit fluctuates less than bank credit. In short, certain empirical phenomena related to the credit channel could be rationalized by assuming that firms set trade credit terms to maximize NPV[3] and take menu costs into account. Finally, similarities to exchange rate pass-throughs and the effectiveness of monetary easing in a pandemic are discussed.

The rest of the paper is organized as follows: Extant literature is reviewed in Section 2, while Section 3 performs the analysis. In Section 4, numerical results show credit terms and product prices are stable even with large changes in interest rates. Menu costs are considered and the Meltzer (1960) effect is shown to hold in Section 5. Section 6 concludes with a discussion of exchange rate pass-throughs and the effectiveness of monetary easing in a pandemic.

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3 The NPV framework is used extensively in textbooks like Maness and Zietlow (2005). In Graham and Harvey's (2001) survey, 75% of firms either always or almost always use both NPV and IRR to evaluate projects. Thus it should be as appropriate to study credit channel transmission of monetary policy in the NPV framework

2. Review of Factors affecting Trade Credit Terms

Many theories have been proposed to explain the use of trade credit by vendors and the determination of credit terms. Credit terms specify when invoiced amounts are due and whether a cash discount could be taken for earlier payment. The *credit period* is the length of time allowable for payment of the invoice amount. The *cash discount* is the percentage amount that can be subtracted from the invoice if the customer pays within the *discount period.* Smith (1987) argues that a supplier provides trade credit in order to protect non-salvageable investment in the client's relationship. Mian and Smith (1992) focus on the information advantage of trade credit over traditional financing. Emery (1984) proposes trade credit as a means of alleviating credit market imperfections, while Emery (1987) emphasizes that trade credit provides the means for the vendor to manage fluctuations in product demand. Brick and Fung (1984) consider the differential of tax rates between a supplier and its buyer as the reason for the provision of trade credit. Petersen and Rajan (1994) suggest credit rationing as a reason, while Schwartz and Whitcomb (1980) and Petersen and Rajan (1997, p.664) suggest price discrimination as a motive for trade credit.

Equally, if not more, important as the abovementioned theories of trade credit are those that integrate credit policy with other policy decisions. It has been recognized (Kim and Atkins, 1978; Kim and Chung, 1990) that suboptimal results will occur whenever interrelated policy variables are modeled independently. Therefore, it is desirable that credit management decisions be made jointly with other policy decisions. Perhaps the most important area of integration is the integration of a firm's credit policy with its product pricing as recognized by Kim and Atkin (1978, p.403) who state that "it is conceptually incorrect to analyze credit programs in isolation of pricing schemes." Their paper, along with Atkins and Kim (1977), use wealth-maximizing frameworks in their integrating efforts.

The determination of an optimal cash discount from a theoretical perspective originated with Lieber and Orgler (1975) who developed expressions for the expected net present value or NPV of accounts receivable and implicit form solutions of the optimal discount. Later, Hill and Riener (1979) derived an explicit form solution of an optimal discount in a situation where the firm has no bad-debt exposure and the fraction of buyers discounting is known with certainty. Beranek (1991) provided analysis of behavioral factors determining the optimal cash discount. Recognizing that the provision of a cash discount is equivalent to a reduction in price, Rashid and Mitra (1999) linked it to the price elasticity of demand. Further recognizing that a cash discount for early repayment separates buyers with respect to their borrowing costs, Lim and Rashid (2002, 2008) introduce a partial equilibrium model of third-degree price discrimination where the firm sets two prices to maximize NPV: a product price, and a cash discount (which determines the effective price in the second market). Setting two prices then requires two elasticities: a cash discount elasticity of demand (which measures the sensitivity of sales to the cash discount or credit terms in general[4]), and the product price elasticity of demand (which measures the sensitivity of sales to the product price). The main conclusion of their paper is that *the effect of the cash discount elasticity is mainly on the optimal cash discount, while the effect of product price elasticity is mainly on the optimal product price*.

3. Theoretical Analysis

In order to solve for the product price, P, and the cash discount, d, Lim and Rashid (2002, 2008) needed two separate elasticities of demand, Q: (a) the cash discount elasticity of demand, denoted by η_d, where:

$$\eta_d = \frac{\partial . Q}{\partial \ d} \frac{d}{Q} \tag{1}$$

and (b) the product price elasticity of demand, denoted by η_p, where:

$$\eta_p = \frac{\partial . Q}{\partial \ \bar{p}} \frac{\bar{P}}{Q} \tag{2}$$

[4] Lim, Rashid and Mitra (2006) find that credit terms are positively correlated with each other. Therefore, a higher cash discount implies more generous credit terms.

Since this paper builds on the model of Lim and Rashid (2002, 2008), it is essential that the assumptions, notation and the model be presented briefly.

A single period framework is assumed. At the beginning of the period, both production and sale of Q quantity of output takes place, with the variable cost per unit, v, assumed to be constant. Given the length of credit period N_2 days, the firm considers providing a cash discount rate, d, for early repayment of invoices by customers. If a cash discount is provided, we denote the discount period as N_1 days. The sales are assumed to be uniformly distributed among customers. We assume that p fraction of customers take the cash discount, and of the (1-p) fraction that decline the cash discount, a λ fraction of these customers pay on day N_2. Thus, (1-p)(1-λ) fraction of customers are those who do not take the cash discount and do not pay on day N_2. This (1-p)(1-λ) fraction therefore default and become a bad debt loss. The firm sets not only the value of d but also the level of $\bar{P}$. Assuming that the annual cost of short-term funds, k, is initially constant, the net present value of accounts receivable is given by:

$$V = p(1-d)PQ(1+k)^{-N1/360} + (1-p)\lambda PQ(1+k)^{-N2/360} - vQ \qquad (3)$$

The first term represents the present value of payments by customers who take the cash discount, while the second term represents the present value of payments by customers who do not take the cash discount and pay on day N_2. The last term gives the variable cost of production, Q. The firm's problem is to optimally choose the cash discount rate, d, and the product price, P. The optimal cash discount rate and product price will be denoted by d* and P* respectively. The separation of customers to those taking the cash discount and those not taking the cash discount makes the model one of third-degree price discrimination, similar to the model in Layson (1998). Layson denotes each market by 1 and 2, and denotes price and quantity by p and q. Equation (3) above would then be a special case of Layson's (1998) profit function, $\pi(p_1,p_2)=p_1q_1+p_2q_2-C(Q)$, where $p_1=P(1-d)(1+k)^{-N1/360}$, $p_2=P(1+k)^{N2/360}$, $q_1=pQ$, $q_2=(1-p)\lambda Q$ and $C(Q)=vQ$. As our model is one of price discrimination, we would also require the three conditions for price discrimination to exist as postulated by Carroll and Coates (1999): (i) the firm must have some market power; (ii) there can be at best imperfect arbitrage opportunities; and (iii) customers must have different price elasticities of demand. The imperfect arbitrage opportunities result from imperfect financial markets (Emery, 1984). Behavioral specifications of p, λ and Q are given in Appendix 1. The theoretical derivation of the simultaneous equations determining the optimal cash discount rate and product price is shown in Appendix 2. The simultaneous equations are:

$$\frac{\partial Z}{\partial d} = \theta \left\{ \frac{\partial p}{\partial d}(1-d) - p \right\} d - \frac{\partial p}{\partial d}\lambda d + \theta(1-d)\eta_d - \frac{\sigma \eta_d}{\bar{P}} = 0 \qquad (4)$$

$$\frac{\partial Z}{\partial \bar{P}} = \theta p(1-d)(1+\eta_{\bar{P}}) + (1-p)\lambda(1+\eta_{\bar{P}}) - \frac{\sigma \eta_{\bar{P}}}{\bar{P}} = 0 \qquad (5)$$

where $Z = V(1+k)^{N_2/360}$, $\theta = (1+k)^{(N_2-N_1)/360}$ and $\sigma = v(1+k)^{N_2/360}$. Z is then the NPV of accounts receivable at the end of the credit period N_2. Equations (4) and (5) constitute a system of simultaneous equations in d* and P* where η_d and η_P play an important role. In equation (4), the effect of η_d is embodied in the last two terms as the first two terms simply represent a trade-off between the time value of money of early receipt of payment and the cash discount expense. In equation (5), if $\eta_P=-1$, the first order condition cannot be satisfied because the first two terms become zero while the last term is positive. For $0<|\eta_P|<1$, all three terms in equation (5) are positive, again making it impossible for this condition to hold.

4. Numerical Results

For the solution of the simultaneous system in equations (4) and (5), a specific relationship between p and d has to be assumed. Following Rashid and Mitra (1999), we assume p=Bd where B is a positive constant. Instead of recursive substitution used by Rashid and Mitra (1999) and Lim and Rashid (2002, 2008), we solve equations (4) and (5) using the "Solver" tool in MS Excel. Using empirical estimates from the 1993, 1998 and 2003 National Survey of Small Business Finances as reported in Lim, Rashid and Mitra (2006) and bad debt estimates found in Scherr (1989), the model is calibrated as follows: $\lambda = 0.99$; k = 10% per annum; v = \$0.8 per unit of output; $N_1 = 10$ days; $N_2 = 30$ days; B = 10. For a selected pairs of values of η_d and η_p, Table 1 presents optimal cash discount rates and optimal product prices.

Table 1 Optimal Cash Discount Rates and Optimal Product Price at Various Demand Elasticities

η_d \ η_p	d* (top of each cell), P* (bottom of each cell)			
	-1.5	**-2.0**	**-2.5**	**-3.0**
0.005	0.0172 \$2.444	0.0155 \$1.629	0.0144 \$1.357	0.0137 \$1.222
0.01	0.0222 \$2.447	0.0199 \$1.631	0.0183 \$1.358	0.0171 \$1.222
0.015	0.0262 \$2.451	0.0233 \$1.632	0.0213 \$1.359	0.0199 \$1.223
0.02	0.0295 \$2.454	0.0261 \$1.634	0.0238 \$1.360	0.0222 \$1.224

As noted in Lim and Rashid (2002, 2008), higher (lower) is the product price elasticity of demand, lower (higher) is the optimal product price. Also, higher (lower) is the cash discount elasticity of demand, higher (lower) is d*. *As customers with higher cash discount elasticities have higher borrowing costs, this explains survey evidence that customers with higher borrowing costs are offered higher cash discounts*. As η_d rises, the rate of increase in d* slows down. We also find what Lim and Rashid (2002, 2008) term a "simultaneity effect", that is, the cash discount is directly related to the contribution margin, and results from the assumption of interdependent demands. The effect of the cash discount elasticity η_d on the optimal cash discount d* is much larger than the effect of the product price elasticity η_p on d*. This confirms Lim and Rashid's (2002, 2008) main theoretical finding for a 60-day credit period and is consistent with Lim, Rashid and Mitra's (2006) empirical evidence as described in Section 1. For most grids of η_d and η_p, the numerical values of d* are around 2%. Lim, Rashid and Mitra (2006) examine buyer firms from the 1993, 1998 and 2003 National Survey of Small Business Finances and find that the median and mode discount rates are 2%. Ng, Smith and Smith (1999) examine supplier firms and find the same 2% discount. Maness and Zietlow (2005) present an overview of cash discount practices consistent with competitive suppliers offering a 2% discount. For the three pairs of the two elasticities, Table 2 illustrates the effect of k on d* and P*. Note that while k increases from 0% to 20%, with $(\eta_d,\eta_p) = (0.005,-1.5)$, the optimal cash discount only increases from 1.55% to only 1.87% while the optimal product price increases from \$2.43 to only \$2.46. Similar results are observed for other pairs of elasticities. Therefore, *credit terms and product prices are stable even with large changes in macroeconomic interest rates*.

Table 2: Effect of Variations in k on d* and P* at three Selected Pairs of η_d and η_p

d* (top of each cell), P* (bottom of each cell)

k (%) η_d , η_p	0	5	10	15	20
0.005, -1.5	0.0155 $2.426	0.0164 $2.436	0.0172 $2.444	0.0179 $2.453	0.0187 $2.461
0.02, -1.5	0.0280 $2.437	0.0287 $2.446	0.0295 $2.454	0.0302 $2.462	0.0309 $2.470
0.005, -3	0.0119 $1.212	0.0128 $1.217	0.0137 $1.222	0.0145 $1.226	0.0154 $1.230

5. Adding Menu Costs to the Model.

Menu costs refer to the direct costs of price adjustment (like changing a menu). Zbaracki *et al.* (2004) identify and measure three types of managerial costs (information gathering, decision-making, and communication costs) and two types of customer costs (communication and negotiation costs) related to price adjustment. They find that the managerial costs are more than six times, and customer costs more than twenty times, the menu costs, confirming McCallum's (1988) notion that menu costs are of insignificant magnitude. In total, the price adjustment costs comprise 1.22% of the company's revenue, with menu costs comprising just 3.57% of the total price adjustment costs (or 0.0435% = 3.57%*1.22% of the company's revenue). Zbaracki *et al.* (2004, pp. 523 and 530) have excluded fixed costs from their calculations. Thus a company would incur menu costs of 0.0435% of revenues *each time a price change is made*. Also, the estimates of menu costs obtained from Zbaracki *et al.* (2004) are for a billion-dollar company. If there are economies of scale in menu costs, then a smaller company would incur menu costs larger than 0.0435% of revenues.

A profit-maximizing firm would only change its credit terms when the increase in the NPV of its accounts receivables exceeds the menu costs. With the NPV of accounts receivables, V, given by equation (3), the revenues are given by the first two terms. The increase in NPV as a percentage of revenues is calculated in Appendix 3. Suppose that k is initially at 5%. Also suppose (η_d,η_p)= (0.005,-1.5). From Table 2, d* is 1.64% and P* is $2.436. Now if the central bank raises short-term interest rates such that k is now 10%, the firm must decide whether to change d and P to their new optimal levels of 1.72% and $2.444 respectively. Assuming that k stays at 10% for the next 30 days, in our model, the menu costs at the end of the credit period is 0.0435%*1.1^(30/360) = 0.0438% of revenues. The firm will change d and P if ΔZ is greater than 0.0438%. Now Zd = 2.575% and Zp = 0.07%. Both Zd and Zp are evaluated at the old optimum of d=1.64% and P=$2.436, but with k=10% (i.e., at the new value of k which is exogenous). So Δd = 1.72%-1.64% = 0.08% or 0.0008 and ΔP = $2.4444-$2.4356 = $0.0088. Thus Zd*Δd = 0.00207% of revenues, which is the increase in NPV when the firm optimizes its cash discount, and Zp*ΔP = 0.00063% of revenues, which is the increase in NPV when the firm optimizes its product price. The total increase in NPV when the firm optimizes both d and P is ΔZ = 0.0027% of revenues, which is well below the menu costs of 0.0438% of revenues. Even though NPV increases when the firm optimizes d and P, the increase is much less than the menu costs. Therefore, the firm would optimally choose *not* to change d and P.

Table 3 shows the menu costs (as a percentage of revenues) at the end of the credit period for different levels of k. These menu costs will be compared to the estimates of the increase in NPV from optimizing d and P, as shown in Tables 4 to 8, where each table is for different pairs of elasticities. Tables 4 to 6 have the bad-debt loss falling proportionately as the cash discount, d, increases ($\partial\lambda/\partial d$=0), Table 7 has the bad-debt loss about constant ($\partial\lambda/\partial d$=-0.1), and Table 8 has the bad-debt loss increasing as d increases ($\partial\lambda/\partial d$=-0.625). We assume that k=5% initially, and the central bank can increase k from 5% to the levels of k reported in the tables. For example, k=20% refers to the central bank raising k from 5% to 20% and lists the optimal d* and P* for k=20% and computations of the NPV increase. *The point is to find out how much k must increase from 5% in order for the increase in NPV from optimizing d and P to be larger than the menu costs.*

The second column in each table lists the optimal d* and P* for the respective k. The third column in each table lists the increase in NPV (as a percentage of revenues) when the firm optimizes d, which is Zd*Δd. In order to calculate Zd with ∂λ/∂d nonzero in Tables 7 and 8, we replace Zd with Zd', with Zd' = 100*[(∂Z/∂d)/d + (1-p) * ∂λ/∂d * d]/A where ∂Z/∂d is defined by equation (4). The fourth column in each table lists the increase in NPV (as a percentage of revenues) when the firm optimizes P, which is Zp*ΔP. Note that Zp is unaffected by ∂λ/∂d. The fifth column in each table lists the total increase in NPV (as a percentage of revenues) when the firm optimizes both d and P, which is ΔZ.

Table 3: Menu Costs as a Percentage of Revenues at End of Credit Period (Day N_2)

K	Menu Costs (% of Revenues)	k	Menu Costs (% of Revenues)
5%	0.0437%	28%	0.0444%
10%	0.0438%	29%	0.0444%
15%	0.0440%	30%	0.0445%
20%	0.0442%	31%	0.0445%
21%	0.0442%	32%	0.0445%
25%	0.0443%	36%	0.0446%
27%	0.0444%	47%	0.0449%

Table 4: Increase in NPV as a Percentage of Revenues at End of Credit Period (Day N_2)
(η_d,η_p) = (0.005,-1.5); ∂λ/∂d= 0

k	d*, P*	Zd * Δd	Zp * ΔP	ΔZ
5%	0.0164, $2.436	-	-	-
10%	0.0172, $2.444	0.00207%	0.00063%	0.00270%
15%	0.0179, $2.453	0.00805%	0.00239%	0.01044%
20%	0.0187, $2.461	0.0176%	0.0051%	0.0227%
25%	0.0195, $2.468	0.0304%	0.0088%	0.0392%
27%	0.0198, $2.471	0.0364%	0.0104%	**0.0468%** [2]
30%	0.0202, $2.476	**0.0461%** [1]	0.0132%	**0.0593%** [2]

[1] NPV Increase from Change in Cash Discount Only Exceeds Menu Costs
[2] NPV Increase from Change in Cash Discount and Product Price Exceeds Menu Costs

Table 5: Increase in NPV as a Percentage of Revenues at End of Credit Period (Day N_2)
(η_d,η_p) = (0.02,-1.5); ∂λ/∂d= 0

k	d*, P*	Zd * Δd	Zp * ΔP	ΔZ
5%	0.0287, $2.446	-	-	-
10%	0.0295, $2.454	0.00185%	0.00055%	0.00240%
15%	0.0302, $2.462	0.00717%	0.00208%	0.00925%
20%	0.0309, $2.470	0.0156%	0.0045%	0.0201%
25%	0.0310, $2.477	0.0267%	0.0077%	0.0344%
28%	0.0319, $2.481	0.0347%	0.0099%	**0.0446%** [2]
32%	0.0324, $2.487	**0.0466%** [1]	0.0132%	**0.0598%** [2]

[1] NPV Increase from Change in Cash Discount Only Exceeds Menu Costs
[2] NPV Increase from Change in Cash Discount and Product Price Exceeds Menu Costs

Table 6: Increase in NPV as a Percentage of Revenues at End of Credit Period (Day N_2)
$(\eta_d, \eta_p) = (0.005, -3)$; $\partial\lambda/\partial d = 0$

k	d*, P*	Zd * Δd	Zp * ΔP	ΔZ
5%	0.0128, $1.217	-	-	-
10%	0.0137, $1.222	0.00223%	0.00260%	0.00483%
15%	0.0145, $1.226	0.00869%	0.00992%	0.01861%
20%	0.0154, $1.230	0.0190%	0.0214%	0.0404%
21%	0.0155, $1.231	0.0215%	0.0241%	**0.0456%** [2]
25%	0.0162, $1,234	0.0329%	0.0364%	**0.0693%** [2]
29%	0.0169, $1.237	**0.0464%** [1]	0.0507%	**0.0971%** [2]

[1] NPV Increase from Change in Cash Discount Only Exceeds Menu Costs
[2] NPV Increase from Change in Cash Discount and Product Price Exceeds Menu Costs

Table 7: Increase in NPV as a Percentage of Revenues at End of Credit Period (Day N_2)
$(\eta_d, \eta_p) = (0.005, -1.5)$; $\partial\lambda/\partial d = -0.1$

k	d*, P*	Zd * Δd	Zp * ΔP	ΔZ
5%	0.0139, $2.435	-	-	-
10%	0.0146, $2.443	0.0019%	0.0006%	0.0025%
15%	0.0153, $2.452	0.0074%	0.0024%	0.0098%
20%	0.0161, $2.460	0.0163%	0.0053%	0.0216%
25%	0.0168, $2.467	0.0282%	0.0090%	0.0372%
27%	0.0171, $2.470	0.0339%	0.0107%	**0.0446%** [2]
31%	0.0176, $2.476	**0.0464%** [1]	0.0144%	**0.0608%** [2]

[1] NPV Increase from Change in Cash Discount Only Exceeds Menu Costs
[2] NPV Increase from Change in Cash Discount and Product Price Exceeds Menu Costs

Table 8: Increase in NPV as a Percentage of Revenues at End of Credit Period (Day N_2)
$(\eta_d, \eta_p) = (0.005, -1.5)$; $\partial\lambda/\partial d = -0.625$

k	d*, P*	Zd * Δd	Zp * ΔP	ΔZ
5%	0.0058, $2.433	-	-	-
10%	0.0060, $2.442	0.0007%	0.0007%	0.0014%
15%	0.0063, $2.451	0.0027%	0.0027%	0.0054%
20%	0.0065, $2.459	0.0060%	0.0057%	0.0117%
30%	0.0071, $2.475	0.0164%	0.0147%	0.0311%
36%	0.0074, $2.484	0.0250%	0.0217%	**0.0467%** [2]
47%	0.0081, $2.499	**0.0452%** [1]	0.0367%	**0.0819%** [2]

[1] NPV Increase from Change in Cash Discount Only Exceeds Menu Costs
[2] NPV Increase from Change in Cash Discount and Product Price Exceeds Menu Costs

Tables 3 to 8 clearly show that for small changes in k (say from 5% to 10%), the increase in NPV from optimizing d and P is dwarfed by menu costs. The tables also show that the central bank would need to increase k by over 15% from k=5% to k=20% (at least) for the benefits of increasing trade credit interest rates to outweigh the menu costs. NPV increases most in the case of demand that is product-price elastic $(\eta_d, \eta_p)=(0.005, -3)$, and appears to increase less when bad-debt loss increases $\partial\lambda/\partial d = -0.625$) than when bad-debt loss decreases ($\partial\lambda/\partial d = 0$). Apparently, firms facing highly price-elastic products or reductions in bad-debt loss from increasing the cash discount are more likely to increase the cash discount in periods of tight money.

Although uncommon in the United States in recent decades with historically low inflation, absolute short-term rate changes over 15% could be recent phenomena in some countries, explaining World Bank survey evidence that trade credit fluctuates more in such countries. For example, the World Bank has survey evidence that trade credit fluctuated significantly after financial crises in developing countries when short-term interest rates fluctuated between 9 and 44 percentage points over a month.[5]

5. Conclusion

In this paper, numerical computations showed that credit terms and product prices are stable even with large changes in macroeconomic interest rates. Using a menu cost estimate by Zbaracki *et al.* (2004) of just 0.0435% of revenues, it would require an increase in short-term interest rates from 5% to over 20% for the benefits of increasing trade credit interest rates and product prices to outweigh the menu costs. Although uncommon in the United States in recent decades with historically low inflation, absolute short-term rate changes over 15% could be recent phenomena in some countries, explaining World Bank survey evidence that trade credit fluctuates more in such countries (e.g., Indonesia, South Korea and Thailand in the Asian financial crisis of the late 1990s). This finding led to our main conclusion that the empirical phenomena of credit terms and product prices being stable over time (in the United States in recent decades) and of the Meltzer (1960) effect could be rationalized by assuming that firms set credit terms to maximize NPV and take menu costs into account.

Our results on credit policy have some commonality with the literature on exchange rate pass-throughs. In the early years of floating exchange rates, economists expected to find a close association between movements in exchange rates and national price levels. Based on purchasing-power parity, it was felt that control of domestic inflation would become more problematic in an environment of exchange rate volatility. However, a substantial literature, covering many countries, has documented that exchange rate changes are, at best, weakly associated with changes in domestic prices at the consumer level. The low-degree of "exchange rate pass-through" both at the disaggregated level, for individual traded goods prices, and more generally, in aggregate price indexes, has been extensively documented. (Devereux and Yetman, 2002, p.347). This led Devereux and Yetman (2002) to develop a simple theoretical model of endogenous exchange rate pass-through that focuses exclusively on the role of price rigidities that come about because of the presence of "menu costs". In their model calibration, they find that for annual rates of inflation higher than 25 percent, firms will adjust prices every period so price rigidity disappears completely. In that case, the pass-through from exchange rate changes to prices is complete. In short, in countries with very high inflation (or very high interest rates), prices become essentially flexible as the cost to firms of maintaining fixed prices fully offsets the menu costs. In our model, firms only adjust credit terms and product prices when short-term interest rates change more than 15 percent. Pass-throughs to credit terms and product prices are higher in periods with higher nominal interest rates (and thus higher absolute interest rate changes).

Many industrialized countries seemed to have experienced a decline in exchange rate pass-through to consumer prices in the 1990s, despite large exchange rate depreciations in many of them. Bailliu and Bouakez (2004) state the fact that this documented decline in exchange rate pass-throughs in recent years coincided with the low-inflation period that most industrialized countries have entered and that these two phenomena are correlated. Sekine (2006) finds that pass-throughs have declined over time for all his sample countries. The decline in second-stage pass-through (from import prices to consumer prices) is associated with the emergence of a low inflation environment as well as a rise in import penetration. These results are consistent with our model, which predicts that credit terms and product prices would remain stable in recent decades due to low inflation.

Outside of the United States and other industrialized countries, however, credit terms have *not* been stable, especially in countries which suffered through financial crises. Devereux (2001) presents evidence that exchange rate pass-through is very rapid for emerging markets, but slow for advanced economies. He quotes the Governor of the Central Bank of Mexico, Guillermo Ortiz, who stated on 24 June 1999 that: "The pass-through of exchange rates to inflation was much higher in Mexico than in Canada, Australia or New Zealand. And this has to do a lot with history, with credibility of monetary policies, and this is one of the big challenges that we are facing today in Mexico in the conduct of monetary policy. And we have to really build sufficient credibility so that this pass-through from exchange rate movements to inflation ceases to be such an automatic reaction."

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[5] See Dwor-Frecaut *et al.* (2000) and Love and Zaidi (2003) studies on Indonesia, South Korea and Thailand as reported in the World Bank's *Global Development Finance 2004* publication.

Our model suggests that the stability of credit terms in the United States is due to the credibility established by the Federal Reserve in maintaining a low and stable inflation environment where short-term interest rate changes are gradual. The converse would, however, also be true. Monetary easing in times of recession (like during a pandemic) may not result in lower trade credit interest rates or more generous credit terms as the benefits of companies changing credit terms might be offset by menu costs. This explains the common observation that trade credit or credit card interest rates remain high even though the federal funds rate is near zero.

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Appendix 1. Behavioral Specifications in Theoretical Model

A1a. The Specification of p:

$$p = p\ (d, P), \quad \text{where} \quad \delta p/\delta d > 0 \quad \text{and} \quad \delta p/\delta P = 0 \qquad \text{(A1)}$$

The excess of the opportunity cost of not taking the cash discount over individual borrowing rates of marginal customers after an increase in the cash discount explains why $\delta p/\delta d > 0$. It is this proportion, p, which reflects the demand interdependencies of the two markets. If a larger proportion of customers take the cash discount with an increase in d, demand in the other market (those not taking the cash discount) must fall. Next, with a reduction in the product price, the amount of borrowing needed declines, which may result in lower borrowing rates. If this happens, then the effect on p is positive. On the other hand, with a reduction in product price, quantity demanded rises, requiring more borrowing and perhaps higher borrowing rates. If this happens, then the effect on p is negative. It is difficult to know which of the two opposing effects is stronger. Therefore, we let $\delta p/\delta P = 0$ throughout.

A1b. The Specification of λ:

$$\lambda = \lambda\ (d,P), \text{ where} \quad \delta\lambda/\delta d \le 0 \quad \text{and} \quad \delta\lambda/\delta P = 0 \qquad \text{(A2)}$$

$\delta\lambda/\delta d = 0$ requires that among the customers who are not taking the cash discount, the percentage of those who would have paid on day N_2 and the percentage of those who would have defaulted is unchanged after an increase in the cash discount. $\delta\lambda/\delta d > 0$ implies that, with an increase in the cash discount, customers who would have defaulted as a fraction of the customers who do not take the cash discount decrease. This effect is quite unlikely. Thus, we postulate that $\delta\lambda/\delta d$ is either negative or has the highest value of zero. Initially we would let $\delta\lambda/\delta d=0$. With $\delta p/\delta P=0$, we may expect the bad-debt loss $(1-p)(1-\lambda)$ to increase when the product price increases (i.e., $\delta\lambda/\delta P<0$). However, with a uniform distribution of a decrease in quantity demanded among customers, there is no reason why the bad-debt loss should increase. Therefore, we let $\delta\lambda/\delta P= 0$.

A1c. The Specification of quantity demanded, Q:

$$Q = Q\ (d,P) \text{ where } \delta Q/\delta d \ge 0 \text{, and} \quad \delta Q/\delta P \le 0 \qquad \text{(A3)}$$

There are two notable points about equation (A3). Firstly, $\delta Q/\delta d \geq 0$, as an increase in d signifies a reduction in the effective price, or increased generosity of credit terms. Secondly, $\delta Q/\delta P \leq 0$ reflects the law of demand which states that, ceteris paribus, a lower (higher) product price raises (lowers) quantity demanded of the product (unless the firm's demand curve is perfectly price inelastic in which case $\delta Q/\delta P=0$).

Appendix 2. Determination of optimal cash discount rate and product price

Noting the above behavioral assumptions, the first order conditions for optimality are obtained by differentiating equation (3) with respect to the cash discount rate, d, and the product price, P (with $\delta\lambda/\delta d = 0$ initially) and equating the resulting expressions to zero:

$$\frac{\partial V}{\partial d} = \frac{\partial p}{\partial d}(1-d)\bar{P}Q(1+k)^{-N_1/360} - p\bar{P}Q(1+k)^{-N_1/360}$$
$$-\frac{\partial p}{\partial d}\lambda\bar{P}Q(1+k)^{-N_2/360} + \bar{P}(1-d)\frac{\partial Q}{\partial d}(1+k)^{-N_1/360} - v\frac{\partial Q}{\partial d} = 0 \qquad \text{(A4)}$$

$$\frac{\partial V}{\partial \bar{P}} = p(1-d)Q(1+k)^{-N_1/360} + p(1-d)\bar{P}\frac{\partial Q}{\partial \bar{P}}(1+k)^{-N_1/360}$$
$$+(1-p)\lambda Q(1+k)^{-N_2/360} + (1-p)\lambda\bar{P}\frac{\partial Q}{\partial \bar{P}}(1+k)^{-N_2/360} - v\frac{\partial Q}{\partial \bar{P}} = 0$$

(A5)

Note that for the present value of incremental sales due to the incremental cash discount (the fourth term in equation (A4)), all incremental customers must take the cash discount. That is, the terms involving $\delta Q/\delta d$ which measure the change in V from changing d must have p=1. Further discussion of these first-order conditions are found in Lim and Rashid (2002, 2008).[6] Using the definitions of η_d and $\eta_{\bar{P}}$, re-arrange equations (A4) and (A5) as follows:[7]

$$\frac{\partial Z}{\partial d} = \theta\left\{\frac{\partial p}{\partial d}(1-d) - p\right\}d - \frac{\partial p}{\partial d}\lambda d + \theta(1-d)\eta_d - \frac{\sigma\eta_d}{\bar{P}} = 0 \qquad (4)$$

$$\frac{\partial Z}{\partial \bar{P}} = \theta p(1-d)(1+\eta_{\bar{P}}) + (1-p)\lambda(1+\eta_{\bar{P}}) - \frac{\sigma\eta_{\bar{P}}}{\bar{P}} = 0 \qquad (5)$$

where $Z = V(1+k)^{N_2/360}$, $\theta = (1+k)^{(N_2-N_1)/360}$ and $\sigma = v(1+k)^{N_2/360}$

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[6] In equation (A4), the incremental customers are not divided into those who take cash discount and those who do not. The reason is simple: the incremental cash discount represents a price reduction only to those who take the cash discount. Otherwise there is no reduction in price. Thus, all incremental customers must take the cash discount.

[7] Each term in equation (A4) is divided by PQ and multiplied by d. Each term in equation (A5) is divided by Q. Terms in both equations are multiplied by $(1+k)^{N_2/360}$.

Appendix 3. Determination of NPV increase as a percentage of revenues

To determine the NPV increase as a percentage of revenues, we use equations (A4) and (A5), divide these two equations by revenues, and then multiply by 100. Note that PQ is factored out of equations (A4) and (A5) in the numerator as well as the first two terms of equation (3) in the denominator, thereby canceling out. Simplifying by letting $Z=V(1+k)^{N_2/360}$ denote NPV at the end of the credit period N_2 and $A=p(1-d)\theta+(1-p)\lambda$ be an adjustment factor, the increase in NPV as a fraction of revenues, ΔZ, is given by:

$$\Delta Z = [(\partial Z/\partial d)/A*d] * \Delta d + [(\partial Z/\partial P)/(A*P)] * \Delta P \qquad (A6)$$

where $\partial Z/\partial d$ is given by equation (9) and $\partial Z/\partial P$ is given by equation (10). Denote $100*[(\partial Z/\partial d)/A*d]$ as Zd and $100*[(\partial Z/\partial P/(A*P)]$ as Zp. Then the increase in NPV as a percentage of revenues is given by:

$$\Delta Z = Zd * \Delta d + Zp * \Delta P \qquad (A7)$$