Switching mortgages: a real options perspective

Céline Gondat-Larralde*and Frank Strobel[†‡]

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Abstract

We use a model of a borrower considering a switch from her current debt product to an alternative when yield rates follow correlated geometric Brownian motions and derive the trigger level of relative yield rates that determines whether the borrower finds exercising the option of switching optimal. We perform a comparative statics analysis, illustrate with numerical examples and calibrate the model for the U.K. mortgage market for the period Oct. 1998 to Sept. 2003; substantial magnitudes of trigger levels can arise even when switching costs are zero, providing an alternative explanation to the inertia observed in borrowers' product choices.

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JEL classification: G1,G2

1 Introduction

When is it optimal for a borrower to switch debt products such as their mortgage? The literature on switching generally implies that a switch will

*GRAPE, Université Montesquieu-Bordeaux IV, France.

[†]Department of Economics, University of Birmingham, UK; corresponding author: f.strobel@bham.ac.uk .

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take place when its net benefit, after switching and potential search costs are accounted for, is just positive.[1] Empirically, it is however found that the actual levels of customer switching behavior in banking are generally low. DTI (2000) finds for instance that only 6% of U.K. current account holders surveyed had switched banks in the last five years, although an additional 15% had contemplated doing so; for mortgages, the equivalent percentages were 12% and 32%, respectively.

This generally low level of switching in banking has been attributed to the presence of switching costs; several empirical studies have shown that various proxies of such costs have a significant impact on prices of banking products.[2] Recent U.K. initiatives to reduce switching costs, following on the Cruickshank (2000) and Competition Commission (2002) reports on competition in U.K. banking markets, have thus e.g. focussed on amending Banking Codes to include detailed time scales for the switching process and led to the introduction of 'ready-made' switching kits by many banks. It has also been suggested that bank customers often underestimate the potential net benefits of changing providers, or that important "trigger events" such as household relocation, branch closure or loan refusal are required to motivate a switch.[3]

Now when the future benefits of such a switch are uncertain, however, and switching debt products entails a large degree of irreversibility, we know from the literature on irreversible investment under uncertainty that the option of waiting typically has non-zero value and can lead to substantial degrees of inertia.[4] To investigate this aspect in more detail, we use a simple model of a borrower considering a switch from her current debt product to an alternative when the associated yield rates follow correlated geometric Brownian

[1] See Klemperer (1995) for the theoretical effect of switching costs in a finite-horizon oligopoly setting; see Padilla (1995) or Kim et al. (2003) for an infinite-horizon setting.

[2] See Ausubel (1991), Calem and Mester (1995), Stango (2002) for the U.S. credit card market; Sharpe (1997) for the U.S. retail deposit market; and Gondat-Larralde and Nier (2004) for the U.K. market for personal current accounts.

[3] See Cook et al. (2002) for the pecuniary benefits of switching U.K. financial products; see Kiser (2002) and Howorth et al. (2003) for surveys of the reasons why U.S. deposit holders and U.K. SMEs, respectively, may switch banks.

[4] See e.g. Dixit and Pindyck (1994).

motions. We derive analytically the trigger level of relative yield rates that determines whether the borrower currently finds it optimal to switch debt products or will leave the option of switching unexercised, perform a comparative statics analysis and illustrate our analytical results with some numerical examples. We then calibrate the model for the U.K. mortgage market for the period Oct. 1998 to Sept. 2003 and find that quite substantial magnitudes of trigger levels can arise even when all other costs of switching are zero, providing a potential alternative explanation to the inertia observed in borrowers' product choices.

Section 2 now sets up the model and discusses our theoretical results, section 3 calibrates it for the mortgage market in the United Kingdom, and section 4 concludes the paper.

2 The model

The yield rates $y_{jt} \geq 0$ for (consol) debt products $j = a, b$ are assumed to follow geometric Brownian motions without drift[5]

$$dy_{jt} = \sigma_j y_{jt} dz_{jt} \tag{1}$$

where $\sigma_j > 0$,[6] $dz_{jt} = \varepsilon_{jt}\sqrt{dt}$ are increments of Wiener processes with $\varepsilon_{jt} \sim \text{NID}(0,1)$, and $E_t(dz_{at}dz_{bt}) = \rho dt$ with ρ the coefficient of correlation between the processes z_{jt} (and $-1 \leq \rho < 1$).

The expected present discounted per-unit cost of debt product j is then[7]

$$C_{jt} = E_t \int_t^\infty y_{j\tau} e^{-\mu(\tau - t)} d\tau = \frac{y_{jt}}{\mu} \tag{2}$$

where $\mu > 0$ is the (possibly subjective) discount rate.

The decision of a borrower on whether or not to (irreversibly) switch from debt product a to b, say, then involves solving the Bellman equation for the

[5] A geometric Brownian motion for the yield rate process, unlike e.g. a mean-reverting one, allows for closed-form solutions, and is thus used for analytical ease.

[6] The instantaneous variance rate of y_{jt} is thus σ_j^2.

[7] See e.g. Dixit (1993, eq. (2.7)).

optimal stopping problem

$$F(C_a, C_b) = \max\left\{(1-s)C_a - C_b \ , \ \frac{1}{\mu dt}E_t[dF(C_a, C_b)]\right\} \tag{3}$$

where $F(C_a, C_b)$ is the value of the (real) option of switching from debt product a to b ,[8] the proportionality factor $0 \leq s < 1$ encompasses all other costs of switching, and $(1-s)C_a - C_b$ is the expected discounted benefit from such a move.[9] We can then obtain

Proposition 1 *The trigger level of relative yield rates*

$$\frac{y_a^*}{y_b^*} = \frac{\beta_1}{(1-s)\,(\beta_1 - 1)} > 1$$

where

$$\beta_1 = \frac{1}{2}\left(1 + \frac{1}{\sqrt{1 - \frac{8\,\mu^3}{8\,\mu^3 + {\sigma_a}^2 - 2\,\rho\,\sigma_a\,\sigma_b + {\sigma_b}^2}}}\right) > 1$$

determines whether a borrower switches from debt product a to b (for $\frac{y_a}{y_b} \geq \frac{y_a^*}{y_b^*}$*), or whether the option of switching remains unexercised (for* $\frac{y_a}{y_b} < \frac{y_a^*}{y_b^*}$*).*

Proof. See Appendix. ■

A borrower perceives exercise of the option of switching from debt product a to b as desirable only when the current value of relative yield rates $\frac{y_a}{y_b}$ is greater than (or equal to) the trigger level $\frac{y_a^*}{y_b^*}$ given by Proposition 1; intuitively, the higher the yield rate on a borrower's current debt product relative to the alternative's, the more she stands to gain from switching. While $\frac{y_a}{y_b} < \frac{y_a^*}{y_b^*}$ applies, on the other hand, a borrower strictly prefers to leave the option of switching unexercised and stays with her current debt product for the time being. We note that the trigger level of relative yield rates $\frac{y_a^*}{y_b^*}$ is strictly (and, as we shall see below, potentially substantially) greater than one; the uncertainty surrounding the future evolution of those yield rates

[8] The compound option of possible additional future switches could be included, albeit at considerable analytical cost.

[9] We drop time subscripts for ease of notation.

makes a borrower more reluctant to commit to an irreversible switch that might later prove less advantageous than initially thought.

Turning now to a comparative statics analysis of the trigger level $\frac{y_a^*}{y_b^*}$, we obtain

Proposition 2 *The directional impact of changes in σ_j, ρ, μ and s on the trigger level of relative yield rates $\frac{y_a^*}{y_b^*}$ is*

$$\frac{\partial\left(\frac{y_a^*}{y_b^*}\right)}{\partial\sigma_a} \lesseqgtr 0 \textit{ for } \sigma_a \lesseqgtr \rho\sigma_b$$
$$\frac{\partial\left(\frac{y_a^*}{y_b^*}\right)}{\partial\sigma_b} \lesseqgtr 0 \textit{ for } \sigma_b \lesseqgtr \rho\sigma_a$$
$$\frac{\partial\left(\frac{y_a^*}{y_b^*}\right)}{\partial\rho} < 0$$
$$\frac{\partial\left(\frac{y_a^*}{y_b^*}\right)}{\partial\mu} < 0$$
$$\frac{\partial\left(\frac{y_a^*}{y_b^*}\right)}{\partial s} > 0$$

Proof. See Appendix. ■

We observe that the trigger value $\frac{y_a^*}{y_b^*}$ is increasing in σ_j when that variance rate is sufficiently high; this result is familiar from the standard (financial) option pricing literature as higher uncertainty increases the value of the option of switching and thus raises the trigger value that prompts that option to be exercised. This normal effect is, however, reversed when σ_j falls below a given benchmark; in this case the usual effect of increased uncertainty is dominated by the impact of the two yield rates becoming more symmetric, which reduces the value of the option of switching and thereby lowers the trigger value concerned.[10] The trigger value $\frac{y_a^*}{y_b^*}$ is also decreasing in the correlation coefficient ρ , as the likelihood of the two yield rates drifting apart gets smaller the more correlated these are, decreasing the value of the op-

[10] Note, from eq. (5), the limiting case where $\sigma_a = \sigma_b$ and $\rho = 1$; here the value of the option of switching is zero and the trigger level equals $\frac{1}{1-s}$.

tion of switching. An increase in the discount rate μ similarly leads to lower levels of $\frac{y_a^*}{y_b^*}$: a higher discount rate (i.e. borrowers focussing on a shorter time horizon) raises the opportunity cost of leaving the option of switching unexercised for a further instant, and thus decreases the value of that option. Lastly, the trigger value $\frac{y_a^*}{y_b^*}$ is increasing in the proportionality factor s , as exercising the option of switching becomes less rewarding the higher the other costs associated with such a move.

These qualitative results are illustrated in Figures 1–4, where we graph the trigger value $\frac{y_a^*}{y_b^*}$ for different parameter combinations of σ_j, ρ, μ and s ; it is particularly worthwhile noting the quite substantial magnitudes of $\frac{y_a^*}{y_b^*}$ that can arise even when all other costs of switching are zero, providing a potential alternative explanation to the inertia observed in borrowers' product choices.

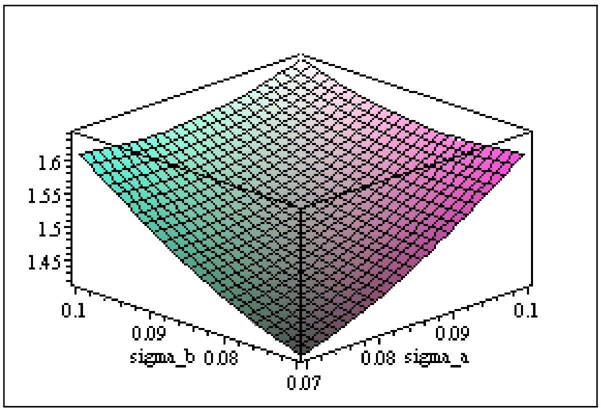

Fig. 1: $\rho = 0.8, \mu = 0.2, s = 0$

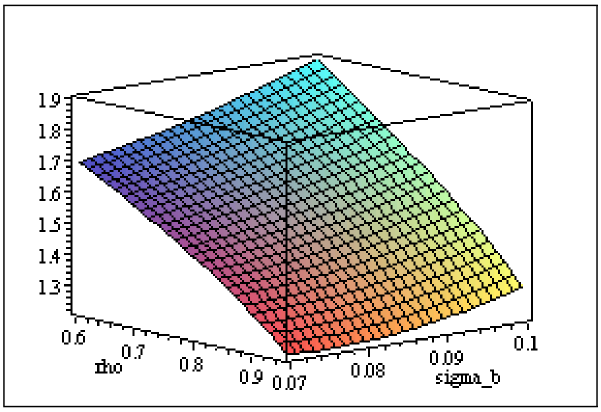

Fig. 2: $\sigma_a = 0.08, \mu = 0.2, s = 0$

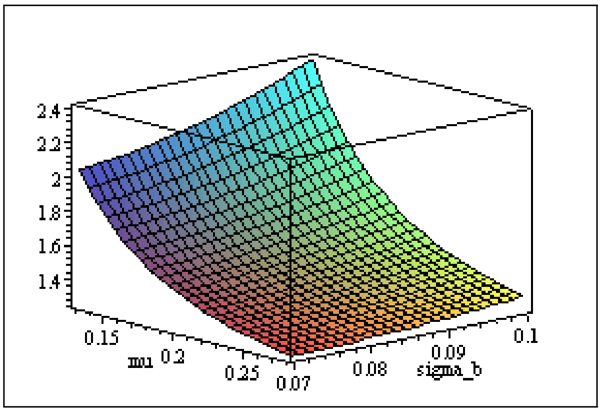

Fig. 3: $\sigma_a = 0.08, \rho = 0.8, s = 0$

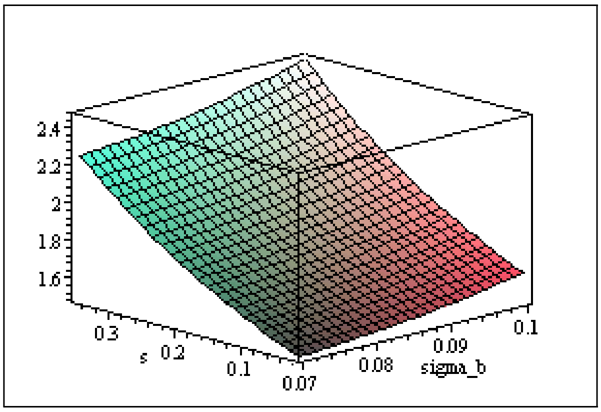

Fig. 4: $\sigma_a = 0.08, \rho = 0.8, \mu = 0.2$

3 A simple calibration

We proceed to calibrate the model described in Section 2 for the mortgage market in the United Kingdom, using monthly data on standard variable rates from October 1998 to September 2003, for a representative sample of lenders extracted from the consumer publication Moneyfacts. We calculate the required (annualized) moments, from the respective transformed series $\ln(\frac{x_t}{x_{t-1}})$ to allow for our distributional assumption of eq. (1), for potential switches to the three most competitive providers in the sample in September 2003, our reference period. Note that the annualized standard deviations σ_j lie within a narrow range of 7.28% to 9.96%, whereas correlation coefficients ρ vary more widely from 0.628 to 0.946. The trigger levels of relative yield rates $\frac{y_a^*}{y_b^*}$, from Proposition 1, are then computed for time horizons of 4 and 8 years by applying discount rates μ of 27.9% and 15.5%, respectively, to allow for differences in borrowers' planning horizons; we assume all other costs of switching are zero here.[11] These results are presented in Table 1, together with the corresponding actual values for the relative yield rates $\frac{y_a}{y_b}$ for September 2003, with results compatible with a current switch highlighted.

We observe from Table 1 that uncertainty about the future benefits of a potential switch clearly has a significant impact on borrowers' decisions of whether or not to switch mortgage providers. For the eight year horizon, none of our results are compatible with borrowers actually switching, with trigger levels in the range of 1.459 to 2.429 whereas actual relative yield rates range from 0.978 to 1.340. To illustrate, if borrowers were to ignore the effect of uncertainty on their optimal switching decision, Table 2 shows the equivalent switching costs, as introduced in eq. (3), that would produce the same trigger ratios;[12] we observe that these range from 31.4% to 58.8% of the present discounted cost of their current mortgage. Note that these are similarly large in magnitude as the switching costs estimated by Kim et al. (2003), who find them to be about one third of the Norwegian market average interest rate on loans.

For the four year horizon, on the other hand, Table 1 indicates that switching from a higher rate mortgage to one of the three most competitive ones becomes optimal in several cases (14 out of 51). It is interesting to note how important the respective variance/covariance structures are in this context, as switching to the most competitive provider in our sample occurs only once, while a switch away from the most expensive provider would not take place at all. Table 2 again illustrates the equivalent switching costs if borrowers were to ignore the presence of uncertainty, which in this case range from 14.5% to 31.4%.

Lastly we examine, also for the four year horizon, what level of (hypothetical) switching costs would make borrowers that properly account for the

[11] Given our infinite horizon framework, these approximate the application of a discount rate r of 5.5% over those finite time horizons T , using $\mu = \frac{r}{1-e^{-rT}}$.

[12] Note that $\frac{y_a^*}{y_b^*} = \frac{1}{1-s}$ for $\sigma_a = \sigma_b = 0$, as eq. (5) becomes degenerate in this case.

effects of uncertainty indifferent between switching or not. The results are reported in Table 3 and we observe that very modest switching costs in the range of 0.19% to 3.42% would eliminate any potential incentives to switch mortgage providers even in this shorter time horizon scenario. We thus conclude that uncertainty about the future benefits of a potential switch can indeed introduce a significant amount of inertia into borrowers' decisions of whether or not to switch mortgage providers, providing an alternative theoretical explanation to this widely observed empirical phenomenon.

4 Conclusion

We used a simple model of a borrower considering a switch from her current debt product to an alternative when the associated yield rates follow correlated geometric Brownian motions and derived analytically the trigger level of relative yield rates that determines whether the borrower currently finds it optimal to switch debt products or will leave the option of switching unexercised. We also performed a comparative statics analysis, illustrated our analytical results with some numerical examples and calibrated the model for the U.K. mortgage market for the period Oct. 1998 to Sept. 2003; we found that quite substantial magnitudes of trigger levels can arise even when all other costs of switching are zero, providing a potential alternative explanation to the inertia observed in borrowers' product choices.

Appendix

Proof. *(Proposition 1)* For the borrower, postponing a switch from debt product a to b for a further instant dt is optimal in the continuation region of the optimal stopping problem eq. (3), giving the relevant Bellman equation as

$$\mu F(C_a, C_b) = \frac{1}{dt} E_t[dF(C_a, C_b)] \tag{4}$$

Applying Ito's Lemma to eq. (4) and noting that the value function $F(C_a, C_b)$ should be homogeneous of degree 1,[13] so that $F(C_a, C_b) = C_b f(\Gamma)$ where $\Gamma \equiv \frac{C_a}{C_b}$,[14] we obtain

$$\frac{1}{2}\,\left({\sigma_a}^2 - 2\,\rho\,\sigma_a\,\sigma_b + {\sigma_b}^2\right)\Gamma^2\, f''(\Gamma) - \mu^3\, f(\Gamma) = 0 \tag{5}$$

as the differential equation that characterizes the evolution of $f(\Gamma)$ in that region.

We solve equation (5) by standard methods, using the value-matching and smooth-pasting conditions $f(\Gamma^*) = (1-s)\Gamma^* - 1$ and $\frac{\partial f(\Gamma^*)}{\partial \Gamma} = (1-s)$, plus the boundary condition $f(0) = 0$,[15] and thus obtain

$$\Gamma^* = \frac{\beta_1}{(1-s)\,(\beta_1 - 1)} > 1$$
$$\text{where } \beta_1 = \frac{1}{2}\left(1 + \frac{1}{\sqrt{1 - \frac{8\,\mu^3}{8\,\mu^3 + {\sigma_a}^2 - 2\,\rho\,\sigma_a\,\sigma_b + {\sigma_b}^2}}}\right) > 1$$

as the critical (trigger) value Γ^*. From the definition of Γ it then follows that $\frac{y_a^*}{y_b^*} = \Gamma^*$ is the trigger value of relative yield rates $\frac{y_a}{y_b}$ separating the region in (y_a, y_b) space where a borrower's option of switching from debt product a to b remains unexercised (i.e. for $\frac{y_a}{y_b} < \frac{y_a^*}{y_b^*}$) from the one where exercise of that option is immediate (i.e. for $\frac{y_a}{y_b} \geq \frac{y_a^*}{y_b^*}$). ■

Proof. *(Proposition 2)* It is easy to show that $\frac{\partial\left(\frac{y_a^*}{y_b^*}\right)}{\partial \sigma_a} = \frac{-\left((\sigma_a - \rho\,\sigma_b)\,(1+\Omega)^2\right)}{4\,\mu^3\,(-1+s)\,\Omega} \lesseqgtr 0$ for $\sigma_a \lesseqgtr \rho\sigma_b$, where $\Omega \equiv \sqrt{1 - \frac{8\,\mu^3}{8\,\mu^3 + {\sigma_a}^2 - 2\,\rho\,\sigma_a\,\sigma_b + {\sigma_b}^2}} > 0$; $\frac{\partial\left(\frac{y_a^*}{y_b^*}\right)}{\partial \sigma_b} \lesseqgtr 0$ for $\sigma_b \lesseqgtr \rho\sigma_a$ follows analogously by substitution. It can be further seen that $\frac{\partial\left(\frac{y_a^*}{y_b^*}\right)}{\partial \rho} = \frac{\sigma_a\,\sigma_b\,(1+\Omega)^2}{4\,\mu^3\,(-1+s)\,\Omega} < 0$. Lastly, $\frac{\partial\left(\frac{y_a^*}{y_b^*}\right)}{\partial \mu} = \frac{3\left(\left({\sigma_a}^2 - 2\,\rho\,\sigma_a\,\sigma_b + {\sigma_b}^2\right)(1+\Omega) + 4\,\mu^3\,\Omega\right)}{4\,\mu^4\,(-1+s)} < 0$ as ${\sigma_a}^2 - 2\,\rho\,\sigma_a\,\sigma_b + {\sigma_b}^2 > 0$, and $\frac{\partial\left(\frac{y_a^*}{y_b^*}\right)}{\partial s} = -\frac{1+\Omega}{(-1+s)^2\,(-1+\Omega)} > 0$ as $\Omega < 1$. ■

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[13] This adopts the solution strategy in Dixit and Pindyck (1994, p. 210).

[14] Thus, $\Gamma = \frac{y_a}{y_b}$ from eq. (2).

[15] Note that zero is an absorbing barrier for the geometric Brownian motion Γ.

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Table 1: Trigger and actual ratios of mortgage yield rates

Mortgage provider	Annualized Standard Deviation	Correlation coefficient			Ratio of yield rates (Sept 2003)			Trigger ratio of yield rates					
		Egg	Nation-wide	First Direct	Egg	Nation-wide	First Direct	Egg		Nationwide		First Direct	
								4 y	8 y	4 y	8 y	4 y	8 y
Abbey National	0.0728	0.842	0.899	0.878	1.248	1.220	1.234	1.300	1.870	1.232	1.648	1.237	1.664
Alliance & Leicester	0.0733	0.863	0.920	0.900	1.248	1.220	1.234	1.282	1.808	1.211	1.582	1.217	1.600
Allied Irish	0.0911	0.691	0.786	0.752	1.160	1.134	1.147	1.433	2.335	1.339	2.000	1.360	2.073
Bank of Scotland	0.0786	0.877	0.903	0.906	1.250	1.222	1.236	1.263	1.746	1.220	1.611	1.205	1.565
Bradford & Bingley	0.0813	0.851	0.846	0.899	1.248	1.220	1.234	1.285	1.819	1.275	1.785	1.212	1.585
Britannia	0.0782	0.628	0.696	0.652	1.239	1.211	1.225	1.459	2.429	1.392	2.188	1.409	2.248
C&G	0.0829	0.790	0.807	0.794	1.239	1.211	1.225	1.340	2.005	1.311	1.905	1.311	1.906
Coventry BS	0.0795	0.856	0.896	0.889	1.248	1.220	1.234	1.281	1.806	1.226	1.630	1.223	1.620
Direct Line	0.0913	0.863	0.867	0.868	1.061	1.037	1.049	1.275	1.784	1.259	1.735	1.252	1.711
Egg	0.0996	1.000	0.835	0.847	1.000	0.978	0.989	-	-	1.307	1.894	1.291	1.840
First Direct	0.0916	0.847	0.889	1.000	1.011	0.989	1.000	1.291	1.840	1.236	1.660	-	-
Halifax	0.0786	0.897	0.946	0.924	1.239	1.211	1.225	1.242	1.680	1.170	1.459	1.185	1.505
NatWest	0.0742	0.860	0.920	0.886	1.259	1.231	1.245	1.283	1.814	1.209	1.577	1.229	1.637
Nationwide	0.0951	0.835	1.000	0.889	1.023	1.000	1.011	1.307	1.894	-	-	1.236	1.660
Northern Rock	0.0755	0.892	0.943	0.916	1.236	1.209	1.223	1.252	1.713	1.181	1.492	1.198	1.541
Royal Bank of Scot.	0.0908	0.738	0.784	0.769	1.340	1.311	1.325	1.393	2.189	1.341	2.006	1.345	2.020
Woolwich	0.0747	0.921	0.883	0.885	1.248	1.220	1.234	1.225	1.627	1.245	1.688	1.229	1.638
Yorkshire BS	0.0841	0.749	0.790	0.783	1.182	1.156	1.169	1.375	2.128	1.326	1.956	1.322	1.942

Sources: Moneyfacts, standard variable rates for mortgages for the period Oct. 1998 to Sept. 2003. Values for trigger ratios are calculated from Proposition 1, assuming a switching cost s of zero. Results compatible with a switch in Sept. 2003 are highlighted.

Table 2: Equivalent switching costs when uncertainty is ignored

Mortgage provider	Equivalent switching costs (no uncertainty)					
	Egg		Nationwide		First Direct	
	4 y	8 y	4 y	8 y	4 y	8 y
Abbey National	23.1%	46.5%	18.8%	39.3%	19.2%	39.9%
Alliance & Leicester	22.0%	44.7%	17.4%	36.8%	17.8%	37.5%
Allied Irish	30.2%	57.2%	25.3%	50.0%	26.5%	51.8%
Bank of Scotland	20.8%	42.7%	18.0%	37.9%	17.0%	36.1%
Bradford & Bingley	22.2%	45.0%	21.6%	44.0%	17.5%	36.9%
Britannia	31.4%	58.8%	28.2%	54.3%	29.0%	55.5%
C&G	25.4%	50.1%	23.7%	47.5%	23.7%	47.5%
Coventry BS	21.9%	44.6%	18.4%	38.6%	18.2%	38.3%
Direct Line	21.5%	44.0%	20.6%	42.4%	20.1%	41.5%
Egg	-	-	23.5%	47.2%	22.6%	45.7%
First Direct	22.6%	45.7%	19.1%	39.8%	-	-
Halifax	19.5%	40.5%	14.5%	31.4%	15.6%	33.5%
NatWest	22.1%	44.9%	17.3%	36.6%	18.6%	38.9%
Nationwide	23.5%	47.2%	-	-	19.1%	39.8%
Northern Rock	20.2%	41.6%	15.4%	33.0%	16.5%	35.1%
Royal Bank of Scot.	28.2%	54.3%	25.4%	50.2%	25.6%	50.5%
Woolwich	18.4%	38.5%	19.6%	40.7%	18.6%	39.0%
Yorkshire BS	27.3%	53.0%	24.6%	48.9%	24.3%	48.5%

Sources: Moneyfacts, standard variable rates for mortgages for the period Oct. 1998 to Sept. 2003. Values for switching costs are calculated from footnote 10 for the no uncertainty case. Results compatible with a switch in Sept. 2003 are highlighted.

Table 3: Hypothetical switching costs preventing switching when uncertainty is considered

Mortgage provider	Hypothetical switching costs		
	Egg 4y	Nationwide 4y	First Direct 4y
Alliance & Leicester	-	0.78%	1.40%
Bank of Scotland	-	0.19%	2.50%
Bradford & Bingley	-	-	1.78%
Coventry BS	-	-	0.88%
Halifax	-	3.42%	3.22%
NatWest	-	1.79%	1.32%
Northern Rock	-	2.30%	2.06%
Woolwich	1.80%	-	0.41%

Sources: Moneyfacts, standard variable rates for mortgages for the period Oct. 1998 to Sept. 2003. Values for switching costs are calculated from Proposition 1. Only results compatible with a switch in Sept. 2003 are shown.