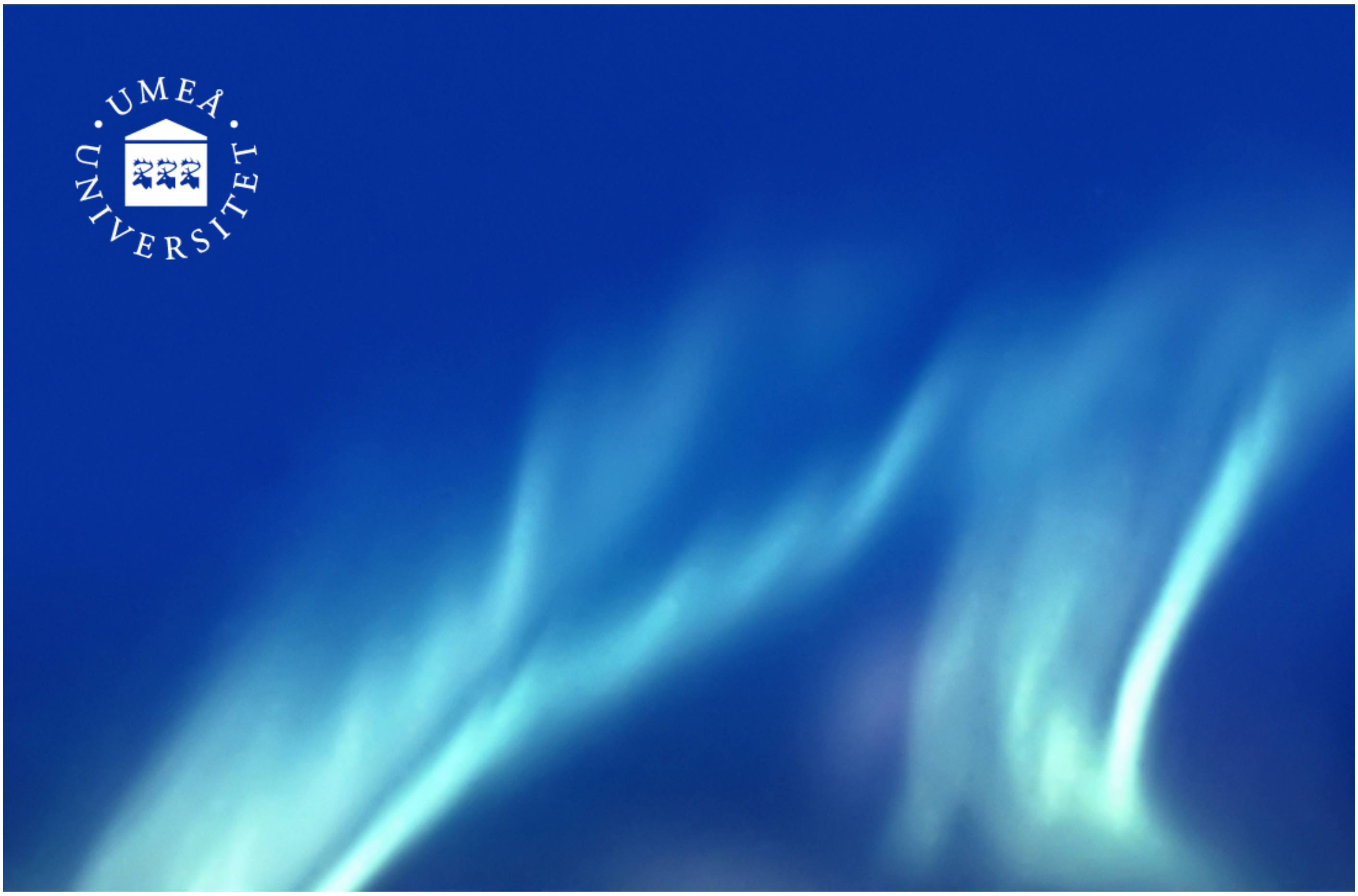

Searching the Mortgage Market:

An Estimated Consumer Search Model of the Swedish Mortgage Market

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Abstract

This paper sets out to explain the observed mortgage rate dispersion in the Swedish mortgage rate market through a consumer search model. Utilizing a structural approach that only requires average mortgage rate data, the search cost distribution for consumers are estimated for the period May 2016 to February 2017. Examining the different contract lengths for mortgages, the three-months and one-year mortgage rates do not fit the consumer search cost framework but the two- tree- and five-year fixed mortgage contracts fits well. The results indicate that there is considerable search cost in the mortgage market and that the low number of searches yields considerable market power to the banks, in the sense of being able to price mortgages above marginal cost. Further the fitted model for the five-year fixed mortgage rate is used to simulate the effects from a cost increase for the banking sector. The results indicates that due to the high consumer search costs present in the market, the mortgages facing the consumers will increase substantially to modest cost increases. A decrease in the consumers search costs are also simulated, which results in lower expected mortgage rates. This paper adds to the literature through the use of average monthly data and a search cost perspective to the question of why there are dispersions of mortgage rates in the Swedish mortgage market.

Key words: Search Cost, Mortgage Market, Price Dispersion

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1. Introduction

For most individuals, taking a mortgage when buying a home is the most important financial decision in their lifetime. Therefore, imperfections on the mortgage market could have substantial welfare effects[1], both on an individual level and to society at large. As signing on too a mortgage could be seen as acquiring a homogeneous good, i.e. financing ones consumption of housing. Following that consumers compare mortgage rates between banks on the basis of price (mortgage rate), one could argue that mortgages are bought on a market in a Bertrand competition setting. To characterize this setting, Bertrand competition is an oligopoly "game" where the firm's strategic variable is prices and the firms sell a homogeneous product. Firms face consumers that will buy from the cheapest firm, and there are no quantity restrictions. In a single period game, the Nash equilibrium for the Bertrand model results in goods being priced at marginal cost as long as there are more than one firm in the market. As mortgages seems to be bought in a Bertrand market, given that banks do not have any clear capacity constraints on the production of mortgages. They also seem to compete with offered mortgage rates (prices), which is what consumers compare. Given that framework, standard arguments regarding Bertrand competition predicts that there should not be any dispersion between mortgage rates offered by individual banks, and that rates (prices) should equal marginal cost (or second lowest marginal cost in the market) given that mortgages are a homogeneous product. (Varian H. R., 1992)

In Sweden there are, and has been, a large number of banks and lenders that offer mortgages to consumers in a competitive framework. As both new borrowers as well as old, have the opportunity to take new loans and re-finance their old, any differences in offered interest rates between the lenders should move consumers to the cheaper alternative, forcing the other to lower their rates until Bertrand equilibrium is reached at mortgage rates priced at marginal cost. But this is not the case in today's Sweden as currently there are substantial differences in the offered rates. Considering the compounding effects over for example a 50-years mortgage, even seemingly small differences in mortgage rates yield large effects over time. These "price" differences with a seemingly homogeneous "good" must then result in some form of

[1] In the sense that yielding market power to firms, generally implies welfare losses compared to fully competitive markets

market imperfection to sustain equilibrium in this market where not all offered rates are the same.

Often when the assumptions in the standard Bertrand case breaks down, the equilibrium strategy of firms in a Bertrand market changes. Instead of a pure strategy of pricing at marginal cost, the profit maximizing strategy becomes a mixed strategy with regards to the firms pricing in equilibrium. In mixed strategy equilibrium, every firm has a probability distribution of possible prices that other firms will charge, and chooses its own probability distribution to maximize their expected profit (Varian H. R., 1992). In this context, it would mean that banks randomize the mortgage rate that they will offer to the consumers, drawn from a probability distribution that maximizes profits given all other banks strategies and the consumer's behaviour.

One possible explanation for this market failure that will be studied in this paper is the presence of consumer search cost as responsible for this phenomenon. Search cost models of consumer behaviour are based the idea that consumers do not have information about the offered prices in the market and retrieving such information is costly (Stigler, 1961).

As the idea that banks are playing a game where they all know their own and others optimal behaviour and respective distributions is a strong assumption, this solution can still be reached indirectly through an evolutionary process such as learning for example. See Samuelson (2002) on evolutionary game theory and its possible mechanism. Also see Hehenkamp (2002) and Alós-Ferrer & Ania (2000) that study Bertrand competition in an evolutionary setting.

The question that this paper aims to answer is: "*Can a search cost models explain the observed dispersion of mortgage rates, and how big are the search costs*?" and "*What are the implications of a change in policy or consumers search costs?"*

At the time of writing, the banks profitability on mortgages is good in Sweden. Since 2009 the bank sectors average margins on a three-months fixed mortgage rate, calculated as the difference between the banks average borrowing rate and their average offered mortgage rates have increased from 0.2% in 2009 to 1.73% in the end of 2016 in a close to zero inflation environment. These increases in the margins are substantial and considerable mark-ups on a

market as important as the mortgage market will certainly have some real welfare consequences.(Finansinspektionen, 2017).
This trend has some important implications and politicians have questioned the banks profitability. In an interview, Sweden’s finance minister said that the banks are making huge profits and therefore a financial tax is needed (SvD Näringsliv, 2017). Although I might question the argument of imposing a tax, just because an industry is profitable, to examine why it is so profitable might also be a way forward. This analysis will also examine what would happen if a policy maker would decide to impose a tax and thus increases the cost and its affects on the pricing of mortgage rates in the market. The analysis also sets out to see how changes of consumers search costs affect the mortgage market.

This analysis uses data on the average mortgage rates for eight of Sweden’s largest banks during the timeframe from May of 2016 to February of 2017. The data covers five different fixed mortgage rate contract lengths, which are three-months (variable rate), one-, two-, three- and five-year. The choice of contract lengths was made on the basis of their universal availability among banks. Using an estimation framework developed by Moraga-González & Wildenbeest (2008), I retrieve the distribution of search costs among the consumers on the Swedish mortgage market as well as the number of searches for mortgage rate quotes. The results indicate that there are considerable search costs and few searches in the market. By fitting a continuous function to the critical search cost values, I then simulate the effects from a cost increase on the pricing of mortgage rates. The result from this are that the expected mortgage rates increase more than the cost increase, as consumers search a lot less while giving higher average mark-ups for the banks. When simulating the effects from a decrease in the consumers search costs, the results in this analysis is that it would lower the average mortgage rate in the market.

2. Literature review

A market where firms compete on the basis of price for a homogeneous good by homogeneous firms, the Bertrand model of oligopoly predicts that the market price will be set to marginal cost as long that there are at least 2 firms. It might seem paradoxical that, according to the Bertrand model, only two firms are needed to bring competition to a socially optimal solution and no profits, then why would firms want to operate in this market? But with consumers that do not search the whole market for the lowest price, pricing strategies with prices over marginal cost emerges and yields market power to the firms. (Varian H. R., 1992)

So why would not consumers find the lowest price in the market and drive firms to a competitive equilibrium? According to Stigler (1961), costly information search for consumers is partly responsible for the price dispersion of homogeneous goods. Consumers cannot assesse all prices, as information is costly to obtain. This must eventually be accounted for in the consumer's utility maximization problem and search behaviour. When facing randomized prices the consumer's utility then is a function of the utility of consumption, but also the expected cost and consumers cost of retrieving information to lower the expected minimum of her sampled prices. Following Stigler, Varian (1980) shows that randomizing prices as a strategy is in the interest of the firms, for example through sales, to uphold a large degree of price dispersion.

In an influential paper regarding consumers search behaviour, Burdett & Judd (1983) conclude that under general conditions and rational agents, equilibrium price dispersion could hold with very small search costs. They present two different frameworks for consumer search behaviour, namely non-sequential and noisy sequential search. The former represent a searching behaviour, where consumer choose their optimal number of searches, before making any search efforts. The latter refers to consumers going from "store-to-store" and updates their decision about searching more at each store. The market equilibrium is then in both cases characterized as a situation where consumers minimize their expected cost of acquiring one unit, and firms maximize their expected profit given correct believes about the consumers.

Trying to estimate the search costs for consumers, has been the focus of many empirical studies. See for example Hortaçsu & Syverson, 2004; Giulietti, Waterson, & Wildenbeest, 2014; Honka, 2014 and Allen, Clark, & Houde, 2014, that study S&P 500 Index Funds, the British electricity market, US auto insurance and the effects on mergers in the Canadian mortgage market respectively. As previous studies show, applying search and other market frictions and estimating their components can be applied to a broad range of markets.

As estimating market frictions is a non-trivial task due to its illusive behaviour[2]. Hong & Shum (2006) develop an estimation framework to retrieve the search cost distribution of consumers through the equilibrium conditions of standard search models and price distributions alone. Building on their work, Moraga-González & Wildenbeest (2008) extend the model to a duopoly case as well as a framework for simulating the effects from an increase in taxes. The structural approach and equilibrium assumptions in frameworks like this might feel a bit restrictive, but they still have some very appealing properties for estimations. As these frameworks do not require anything more than the distribution of prices, the job for the econometrician becomes much easier, compared to an approach where for example every individual's behaviour is studied. This approach also lends itself well to my question, as there is easy to collect banks average interest rates, while consumers' individual behavioural patterns are hard to come by. As both Hong & Shum (2006) and Moraga-González & Wildenbeest (2008) show this approach's applicability to online shopping, in their papers, where prices are easily available, the future use of these methods should be in demand[3]. This is because for the econometrician, searching the Internet for price quotes are a simple task, but getting more detailed information regarding for example sales volumes or production costs are much harder to retrieve. In my analysis this then is convenient since the average and listed mortgage rates has to be posted online by Swedish law, other relevant aspects about consumer behaviour however, are hard to obtain.

Concerning the Swedish mortgage market, earlier literature mostly focuses on the relationships between mortgage rates, interest rate, house prices and their interactions. Hort (2000) analyses how information imperfections affect the responsiveness to shocks of mortgage rates, house prices and sales of homes in Sweden. Studying the monetary transmission mechanisms through mortgage lending Papadamou & Siriopoulos (2012) show how financial and monetary policy shocks affect the credit markets. Studying the consumers' selection into different mortgage rate contracts Hullgren & Söderberg (2013) indicates that the groups that select into different contracts have different characteristics in the Swedish mortgage market.

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[2] Market frictions could be said to be illusive in the sense that one cannot explicitly measure an individual's disutility of having to do a certain activity for example.

[3] Assuming that online commerce and prices facing consumers can be assessed in the future as well.

To the best of my knowledge, there have not been any studies of the Swedish mortgage market and its mortgage rate dispersion through a consumer search perspective. This study adds to the literature by trying to explain the observed differences in average mortgage rates between banks in Sweden through a consumer search model. This study also adds to the literature about search models in general by the use of average mortgage rates, given further assumptions, in the same way as prices have been used in the preceding literature.

3. Background

To define the term mortgage, it is a loan that is used to buy real estate, where the house/apartment is the collateral for the loan (Cecchetti & Schoenholtz, 2011). As of the fall 2010, a mortgage cannot exceed 85% of the market value of the property in Sweden, referred to as the "mortgage-roof" (Finansinspektionen, 2016). Although there are other ways for people to finance their housing, and thereby exceed the 85% debt level for example through so called "Blanco" loans, Credit cards or borrowing from friends and family. This analysis will disregard these forms of financing and focus only on the mortgage market.

3.1 The Swedish Mortgage Market

A brief description of the Swedish mortgage market and its characteristics will be presented in this section. There are a few large banks that control most of the mortgage lending to households that makes up most of the Swedish market. As of June 2016, the six largest with their respective market share are Swedbank (24%), Handelsbanken (23%), Nordea (15%), SEB (15%), SBAB (8%), Länsförsäkringar (6%) and other banks/institutes (9%). Although there are a larger group of firms with considerable market shares when it comes to newly emitted mortgages. (Swedish Bankers' Association, 2016)

Adding to these six actors, the Swedish financial supervisory authority recognizes Danske Bank and Skandiabanken that makes up most of the remaining 9 %, to constitute the whole effective Swedish market for mortgages (Finansinspektionen, 2016).

3.2 Data

In this analysis of the Swedish mortgage market, I have retrieved the monthly average mortgage rates offered by the respective banks. The average interest rates are the yearly interest rate on the mortgage for the respective length of fixed interest rates. Generally, shorter contracts have a lower rate than longer contracts where part of the difference can be seen as insurance from interest rate shocks by risk adverse borrowers as well as differences in capital costs (Konkurrensverket, 2013). The collection was done by visiting each banks official web page and downloading their historical average interest rates (*Genomsnittsräntor*) on each of the different contracts lengths. The rates are required to be made publicly accessible by law. A searching consumer faces some heterogeneity with regard to the presentation on the web pages - potentially to discourage too much search[4]. Due to the fact that banks offer different contract lengths with fixed mortgage rates during that timeframe, for example three-months, one-year, seven-years, etc. I only consider contract lengths that all relevant banks have in their product offering. The different product offerings and difficulty in finding relevant mortgage rates, since list rates are also posted, could be a tactic to make the product choice more complex which is in the interest of firms in general (Grubb, 2015). The contract lengths that are universally available are: three-months (often referred to as variable rate), one-year, two-year, three-year and five-year. For a summary of the offered rates during the 10 months studied, see table 1.

Table 1. Average Monthly Mortgage Rates, all banks

Contract time	Three-months	One-year	Two-years	Three-years	Five-years
Average mortgage rate	1.568%	1.625%	1.625%	1.652%	2.075%
Standard deviation	0.071%	0.088%	0.083%	0.086%	0.117%
Max	1.69%	1.9%	1.75%	1.84%	2.42%
Min	1.43%	1.35%	1.33%	1.51%	1.89%
Observations	80	80	80	80	80

For histograms and the evolution of the banks average mortgage rates over time, see appendix 1.1 to 1.5.

4 I am basing this on the annoying task of retrieving all average mortgage rates and for a non-informed consumer; I believe that this would be a confusing task.

4. The Consumer Search Model

The framework for this analysis of the Swedish mortgage market will be based upon a classical consumer search model. The model I will present in this section is adapted from the model described in Moraga-González & Wildenbeest (2008). Their model in turn is based on Burdett & Judd (1983) as well as Hong & Shum (2006) who add heterogeneous consumer search cost to Burdett & Judd´s model.

4.1 Setting up the consumer search model:

N is the number of banks that offer a homogeneous mortgage contract and r is the unit cost for the representative bank to provide one average mortgage. There is also assumed to be a unit mass of identical consumers, each of which demands one mortgage. Let $\overline{I}$ be all consumers' valuation of the loan, in terms of interest rate to finance their mortgage. This is used the same way as how prices are treated in the literature. Each consumer also learns the interest rate quote from one bank randomly and cost free. Beyond the first quote, the consumer incurs a search cost of c to obtain more quotes from different banks. Also assume that consumers have heterogeneous search costs and that the individuals search cost are randomly drawn from a search cost distribution F_c. A consumer with search cost *c,* sampling from *i* banks incur a total search cost of $i \times c$.

Denote the symmetric mixed strategy equilibrium for the banks by the distribution of mortgage rates as F_I, with density function $f_I(I)$. Let $\underline{I}$ and $\overline{I}$ be the lower and upper bounds of the support for F_I. Since the mixed strategy equilibrium is assumed to be symmetrical, this means that all banks have the same optimal distribution of mortgage rates.

Given firm behaviour, a consumer with the search cost c, will search for *i(c)* number of quotes. Consumers are also assumed to conduct an optimal search behaviour, solving:

$$i(c) = arg \min_{s.t\ i>1} c(i-1) + \int_{\underline{I}}^{\overline{I}} iI\big(1 - F_I(I)\big)^{i-1} f_I(I) dI \qquad (1)$$

As all consumers are assumed to buy one mortgage, to optimize ones search behaviour then entails to minimize the cost of searching (first term), taking into account the expected gains from finding a cheaper alternative (second term). This then means that an optimal search quantity for the individual is when equation (1) is optimized. Since *i(c)* has to be an integer, i.e. consumers search 1, 2 or 3 times and not 1.5 times for example. The minimization problem above induces a partition of the set of consumers into N subsets of q_i, i = 1,2…N, with $\sum_{i=1}^{N} q_i = 1$. This then implies that q_i is the fraction of consumers searching for interest rate quotes at i banks. For example, $q_3 = 0.3$ implies that 30% of consumers search at 3 banks of interest rate quotes for their mortgage. Assume further that q_i is also strictly positive for all *i*.

The partition of consumers is calculated as follows:

Let $\mathbb{E}[I_{1:i}]$ be the expected minimum interest rate in a sample of i banks drawn from the distribution F_I, then

$$\varDelta_i = \mathbb{E}[I_{1:i}] - \mathbb{E}[I_{1:i+1}]\,, for\ i = 1,2,\dots,N-1 \tag{2}$$

Denotes the search cost for the consumer that is indifferent between searching for i and i+1 quotes. As $\varDelta_i$ is a decreasing function[5] of *i,* the fraction of consumers, q_i, sampling i banks for interest rate quotes are:

$$q_1 = 1 - F_c(\varDelta_i) \tag{3a}$$

$$q_i = F_c(\varDelta_{i-1}) - F_c(\varDelta_i)\,, i = 1,2,\dots,N-1 \tag{3b}$$

$$q_N = F_c(\varDelta_{N-1}) \tag{3c}$$

Given consumers search behaviour, it is optimal for banks to mix their offered interests rates. The upper bounds for the banks distribution of offered interest rates must be $\bar{I}$. Banks offering $\bar{I}$ will only serve consumers that do not search more than their initial "free" search and are randomly "assigned" to that bank.

The equilibrium interest rate distribution of banks follow from the indifference condition that they should obtain the same profit level regardless of their offered interest rate in support of F_I. i.e. the following equality must hold:

$$(I - r)\left[\sum_{i=1}^{N} \frac{iq_i}{N}\big(1 - F_I(I)\big)^{i-1}\right] = \frac{q_1(\bar{I} - r)}{N} \tag{4}$$

From this expression, and since the lower bound of a probability distribution is equal to zero i.e. at the lower bound $F_I(I) = 0$, it follows that the minimum interest rate offered is:

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[5] This means that the expected gains from visiting another bank at random decreases with the amount of sampled banks.

$$\underline{I} = \frac{q_1(\bar{I} - r)}{\sum_{i=1}^{N} i q_i} + r \tag{5}$$

According to Moraga-González and Wildenbeest (2008), equations (2) to (5) provide enough structure to estimate the search cost distribution using only price data and in this case, average mortgage rates.

5. Econometric model

5.1 Assumptions about the mortgage market

To estimate the consumer search model and its application to the mortgage market, some further assumptions are needed. As earlier literature on the subject uses prices from individual firms, when studying the mortgage market, micro data on individual contracts for the whole market is practically impossible to attain. Instead of this will I use average offered interest rates from the specific banks. For the average interest rates to behave like prices in the context of search models, the following assumptions need to be made.

Assume that banks set average interest rates in support of F_I. Also assume that consumers are randomly assigned between the banks independently of their personal characteristics and also that banks cost structure and pricing behaviour are similar. These are quite strong assumptions, but still applicable since Finansinspektionen, Sweden's financial supervisory authority, follows the banks lending practices and risk taking (Finansinspektionen, 2016).

Further, assume that the individual *i's* mortgage contract at bank *n* can be assumed to have the following general pricing formula:

$$I_n^i = I_n^i(w_n^i, \rho^i, \pi_n) = r(w_n^i, \rho^i) + \pi_n \tag{6}$$

Where w_n^i is term that captures costs and includes the cost of capital[6], capital requirements, wages etc. for bank *n* to offer the individual mortgage, with the expected value of W_n, ρ^i is the individual *i's* risk-premium which is assumed to have some distribution $\rho^i \sim F_\rho$ with the expected value of μ. π_n is the banks strategic choice variable, i.e. mark-up on mortgages.

[6] The notions capital cost in this context extends to all forms of capital costs, including the banks internal revenue demands from their mortgage divisions for example.

The expected value of bank *n's* mortgages I_n, i.e. the average mortgage offered at bank n is then $\mathbb{E}[I_n^i] = \mathbb{E}[r(w_n^i, \rho^i)] + \mathbb{E}\,[\pi_n]$, as expected cost is $\mathbb{E}[r(w_n^i, \rho^i)] = r_n(W_n, \mu)$, where r_n is bank n's cost of offering the average mortgage, rewriting the expectation yields $I_n = r_n + \pi_n$. Then treating r as the cost for a representative bank and I_n is drawn from F_I. Then if the assumptions hold, average interest rates can behave as prices where *r* is the unit cost and π_n is bank *n's* mark-up.

From the consumers' side, there will also need to be further assumptions for this estimation framework to make sense. The consumers are assumed to know their risk-premium and to expect it to be the same, regardless of bank. There are also search related problems for the banks to offer mortgages, see for example Burke et al. (2012) regarding this, as well as risks for racial discrimination and other discriminatory problems of the mortgage market (Ladd, 1998). But as long as consumers are treated equally good/bad at any bank, this problem can be circumvented in this context. Then, regardless of a consumer's individual characteristics, everyone faces the same expected differences between banks offered mortgage rates in terms of percentage points. Then, as assumed before, individual's search costs are randomly distributed among the consumers, which means that a high-risk and a low-risk borrower have the same probability to have a given search cost. This obviously might have a sampling problem, where for example, low-risk implies high wealth and thus might have a greater opportunity cost than a high-risk and low wealth individual leading to a higher search cost for the low-risk type. This could then impact the result. But there are also the possibility of an opposite effect where the personal characteristics of a low-risk individual, for example financially savvy individual, yields a lot of search at a low cost, and that high-risk individuals are not as financially literate and thus experience a high cost of searching for mortgages. These are problems that only can be answered with high-quality data. In large samples I will still assume that search costs are as good as randomly distributed, which makes the use of average interest rates possible to use in the context to estimate the distribution of search costs.

The econometric models that I will use in this analysis, follows Moraga-González & Wildenbeest (2008) but with the difference of using average monthly interest rates at the different banks in the market instead of prices. I will also assume that each month average mortgage rates are results from a mixed strategy equilibrium in each period (month) and that they are drawn from the same probability distribution. This then means that for every month, the banks play a “game” where they are in equilibrium by drawing mortgage rates from an optimal distribution, correctly taking into account the consumers search behaviour, and thus maximizing the expected profit. The symmetrical equilibrium then entails that all banks have the same profit maximizing mortgage rate distribution and faces the same distribution of consumers. Thanks to symmetry and the assumption that they draw from the same distribution for all time periods, one can use all observed mortgage rates to estimate the model.

For this to hold, the fundamental characteristics of the market need to be similar over the timeframe. Because of this, I will limit the time period studied to May 2016 to February 2017. The Swedish central bank held the interest rate constant at -0.5% and the housing market did not experience any major swings during that period. The advantage of using mortgage rates over several time periods is that the estimated parameters become more efficient with more observations. Since one problem with conducting this kind of analysis, for each month, is that there are only eight relevant banks in the market and even though it is possible to estimate this model with only eight data points, the estimates would likely become hard to draw any conclusions from. This is due to the fact that I use the lowest and highest values in the set of empirical observations as estimates of the lower and upper bounds of the distribution. Then only having eight observations, the bounds could likely be wrongly identified.

5.2 Estimation framework

As this analysis will be conducted using Moraga-González & Wildenbeest (2008) method, I will describe their method below, with the adaptation to my analysis.

The objective is to estimate a collection of points$\{\varDelta_i, q_i\}_{i=1}^{N}$ of the search cost distribution i.e. the cut-off points where consumers are indifferent to search for one more mortgage quote by maximum likelihood (ML). Once these estimates are found, one can construct an estimate of the search cost distribution. One difficulty here is that equation (4) cannot be solved for the equilibrium mortgage rate distribution, which makes it hard to calculate the cut-off points:

$$\varDelta_{\mathrm{i}} = \int_{\underline{\mathrm{I}}}^{\bar{\mathrm{I}}} \mathrm{I}[(\mathrm{i}+1)\mathrm{F_I}(\mathrm{I}) - 1]\big(1 - \mathrm{F_I}(\mathrm{I})\big)^{\mathrm{i}-1} \mathrm{f_I}(\mathrm{I})\mathrm{dI} \quad \text{for } \mathrm{i} = 1,2,\dots,\mathrm{N}-1 \tag{7}$$

According to Moraga-González & Wildenbeest (2008), the method to retrieve the minimum variance estimates is by ML, which also has the advantages of standard hypothesis testing and inference. To do this, rewrite Δ_i as a function of the ML estimates of the mortgage rate distribution. First, rewrite the cut-off points through integration by parts, which yields:

$$\Delta_i = \int_{\underline{I}}^{\bar{I}} F_I(I)\big(1 - F_I(I)\big)^i dI \quad for\ i = 1,2, \dots, N-1 \tag{8}$$

Since the distribution function F_I is assumed to be increasing and thus its inverse function exists. Using equation (4), the inverse function is obtained as:

$$I(z) = \frac{q_1(\bar{I} - r)}{\sum_{i=1}^{N} i q_i (1-z)^{i-1}} + r \tag{9}$$

Using equation (9) in eq. (8) yields:

$$\Delta_i = \int_0^1 I(z)[(i+1)z - 1](1-z)^{i-1} dz \quad for\ i = 1,2, \dots, N-1 \tag{10}$$

By retrieving the ML estimates of $\bar{I}, \underline{I}, r$ and $q_i, i = 1,2 \dots N$, then by the invariance property of ML estimation, it is possible from equation (9) and (10) to get ML estimates of the cut-off points of the search cost distribution $F_c(c)$.

Since the probability distribution function of mortgage rates cannot be obtained in closed form, one needs to rewrite equation (4) by the implicit function theorem as:

$$f_I(I) = \frac{\sum_{i=1}^{N} i q_i (1 - F_I)^{i-1}}{(I - r)\sum_{i=1}^{N} i(i-1) q_i (1 - F_I(I))^{i-2}} \tag{11}$$

Let then $\{I_1, I_2, \dots, I_M\}$ be the vector of observed mortgage rates, assume further that $I_1 < I_2 < \cdots < I_M$.

Then use the minimum value as an estimate for the lower bound and the highest value as the upper bound of the support of $\underline{I}$ & $\bar{I}$. Using these, equation (5) can be rewritten to obtain the cost for the representative bank:

$$\mathrm{r} = \frac{\mathrm{I_1} \sum_{\mathrm{i=1}}^{\mathrm{N}} \mathrm{iq_i} - \mathrm{q_1 I_M}}{\sum_{\mathrm{i=2}}^{\mathrm{N}} \mathrm{iq_i}} \tag{12}$$

Putting this into equation (11) and utilizing the fact that $q_N = 1 - \sum_{i=1}^{N-1} q_i$, one can then solve numerically the ML estimation problem which maximizes the likelihood of observing the empirical mortgage rates, given the parameters $q_i, i = 1,2 \dots N$:

$$\max_{\{q_i\}_{i=1}^{N-1}} \sum_{l=2}^{M-1} log f_I(I_l; q_1, q_2, \dots, q_N)$$

Where $F_I(I_l)$ solves, i.e. the profit from charging any mortgage rate within the mortgage rate distribution should yield the same profit level for the representative bank:

$$(I_l - r)\left[\sum_{i=1}^{N} \frac{iq_i}{N}\left(1 - F_I(I_l)\right)^{i-1}\right] = \frac{q_1(\bar{I} - r)}{N} \quad for\ all\ l = 2,3, \dots, M-1$$

One problem that arises in this estimation framework is that the estimate for *r* is obtained as a function of other parameters and then it might create dependence between the mortgage rate observations. In their paper, Moraga-González & Wildenbeest (2008) addresses these concerns through simulations and concludes that the dependency should not be of any great concern in this estimation framework.

Thanks to the ML approach, the calculation of the standard errors for $q_i, i = 1,2 \dots N-1$ is obtained through the standard way, i.e. by taking the square root of the diagonal elements in the inverse of the negative Hessian matrix, evaluated at the optimum values. (Greene, 2012)

Following Moraga-González & Wildenbeest (2008), as r, q_N and the Δ_i´s are obtained from the transformation of the estimated $q_i, i = 1,2 \dots N-1$, to calculate the standard errors associated with them, one needs to use the delta method. (Greene, 2012)

According to Moraga-González & Wildenbeest (2008) a problem that can arise in this framework is a positive bias of estimated q_i´s due to omitted firms[7]. Since there are a large number of banks that I omit from the analysis, this could be an issue. But I still believe that this is a correct assessment since the banks that I include effectively control the whole market (Finansinspektionen, 2016), and most of the omitted banks are small, niched and/or only serve local markets. Because of this, they violate the assumptions set up in the theoretical model of consumer search where firms are assumed to face the same distribution of consumers. Then a bank "only" serving customers on a small local market for example, do not face the same distribution of consumers as the large ones. They can then not be treated as "playing" in the same market. Heterogeneous aspects of both firms and consumers are a recurring concern in the literature and can induce biased estimates. In this analysis, I will assume that all assumptions hold for large actors on the mortgage market.

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[7] The problem with omitting firms is that I reduce the number of banks that consumers can visit from the true number to eight. This then yields that I cannot estimate the true number of cut-off points and thus the estimates become biased. For this analysis, although, I assume that the omitted banks are irrelevant.

As stated earlier, there are two main search behaviours in the consumer-search literature, namely non-sequential (fixed sample size)- and sequential search, and the choice of modelling framework are of great importance. Generally, the non-sequential model is preferred when there is a fixed-costs component associated with search, and sequential is preferred in the absence of such components. (Hong & Shum, 2006)

Since going to different banks likely have at least some fixed-cost component associated with searching, for example the need to negotiate at each bank, the non-sequential approach seems reasonable. Testing these two models on consumer data, De Los Santos et al., (2012) shows that in online consumer markets, the non-sequential model outperforms the sequential model. Which then also strengthens my argument since a lot of search regarding mortgages can now be done online in Sweden.

On the basis of this, I will use a non-sequential approach when analysing the mortgage market in Sweden. This means that I assume that consumers choose the amount of banks to search at for mortgage rate quotes, i.e. the consumer choose 1,2, or N banks to search for, before getting any quotes.

I will also inspect the data to see if it follows the assumptions of the model, as well as conducting Kolmogorov-Smirnov tests on the distributional fits as a fit measure of my estimated models. (Massey, 1951)

6. Estimation results

Just as Giulietti et al., (2014) and Moraga-González and Wildenbeest (2008), I will use all the observed mortgage rates for each contract length as if it comes from the same distribution, to get more effective estimates. The assumptions that need to hold for this to work are that there are no time trends on the observations in the data, as well as there should not be any persistent ranking in terms of mortgage rates. Given the limited sample size, conducting extensive testing can be problematic. In this analysis, I will assume that prices are distributed continuously, meaning that I assume that the average mortgage rates are from a continuous data generating process. A visual analysis of the data by means of histograms (appendix 1), suggests that this seems to be a reasonable assumption, although there are some outliers that breaks the bell-shaped corves that might be problematic. As one of the assumptions are that the distribution of mortgage rates should be approximately the same over the sample period, there is a problem with outliers for especially the two-year contract (appendix 1.3), where SBAB suddenly and independently lowers their average mortgage rate drastically and thus deviates from the expected behaviour. This could later result in biased estimates for the associated search cost distribution, but could also be an interesting strategic anomaly. Other than that outlier, the mortgage rates seem to be randomly changed within an interval, seemingly independent of one another (appendix 1).

To test if banks are randomly changing their mortgages throughout the sample period, I will test for autocorrelation for the individual banks over time. This will then indicate if the assumption that banks are playing a mixed strategy with regard to their pricing of mortgage rates or not, i.e. randomizing their offered average mortgage rates within the support of $F_I(I)$. I will also test the assumption that all mortgage rates are drawn from the same distribution, with regard to having the same fundamental market characteristics during the selected timeframe. To do this, I will test to see if there are any time-trends in the data through simple regressions, meaning that the average mortgage rates at the different periods should not decrease/increase over time.

6.1 Time trends

To test for time trends in the sample period of mortgage rates, I used an OLS approach to fit a trend line and tested the null hypothesis that the slope of the line is equal to zero at a 5% significance level (Appendix 5). All contracts lengths except one did not reject the null hypothesis. The one that was statistically significant was the two-year fixed mortgage rates. The reason behind this was the mentioned problem with outliers, but even with the outliers, the slope coefficient cannot be said to be economically significant due to its low value (-0.0099394). Given this test, I can continue with the assumption that all mortgage rates are drawn from distributions that rest on similar fundamental supply and demand characteristics.

6.2 Auto correlations

To test the assumption that banks are randomizing their average mortgage rates during the sample period, I will test for auto correlation. This approach is based on the idea that if banks randomize, there would not be any auto correlation of average mortgage rates yeastertoday with respect to average mortgage rates today. I have fitted an ACF (auto correlation function) to each bank for each contract length, and test at a 5% significance level, if there are any significant effects from time lags.

A summary of the tests can be seen in (Appendix 6). As expected, almost all banks that offered mortgage rates did not show any auto correlation. The results from the test where that total of four instances where one-period time lag was significant at a 5% level. But given the fact that I tested a total of 40 different series of mortgage rates, by chance I expected to see some significant results. Considering these tests, I will continue with the assumptions that banks “randomize” their offered average mortgage rates during my sample period.

6.3 Shared mortgage rate distribution

As the framework assumes that the banks are drawing from the same mortgage rate distribution, there should not be any differences in the level of mortgage rates. One could for example use a Kolmogorov-Smirnov test to check the observed distributions of mortgage rates between banks and across time periods. Due to the limited amount of observations and the previous tests mentioned above, I will visually check the differences in the rankings of the banks that offered mortgage rates over time. Although it might not be the most sophisticated method, it is still a valid approach in this context. If my approach in this analysis is valid, the ranking in mortgage rates between banks should differ across time. Looking at the graphs in the appendix (1.1 to 1.5), the mortgage rates sampled seems to not express any significant consistency of their rankings across time, even if the time frame of 10 months are short compared to the length of a mortgage. Two notable exception are the rates for the three-months fixed rates (variable rate) (appendix 1.5) that seems to show that the mortgage rates are layered and do not change in rank and for the three-year rates (appendix 1.2) that have two banks with considerably higher mortgage rates. The reason behind this could be several and should be considered when analysing the results.

6.4 Estimated search cost distributions

When estimating the search cost distributions, I will scale up all mortgage rates with a factor of 100. This will then yield units in basis points instead of percentage points. The reason behind this is purely of convenience to make the results easier to interpret with fewer decimal points. The results of the estimation of the fractions that search *i* times can be seen in table 2.

Table 2: Estimated Search Cost Distributions

Contract lengths	Three-months	One-year	Two-years	Three-years	Five-years
$\underline{I}$	143	135	152	151	189
$\overline{I}$	169	190	175	184	242
N	8	8	8	8	8
M	80	80	76	80	80
q_1	0.89 (0.16)	0.56 (0.01)	0.66 (0.03)	0.53 (0.06)	0.39 (0.13)
q_2	0.11 (0.15)	0.33 (0.02)	0.28 (0.03)	0.40 (0.05)	0.51 (0.06)
$q_3 \rightarrow q_7$	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
q_8	0.01 (0.02)	0.10 (0.01)	0.06 (0.01)	0.07 (0.02)	0.10 (0.10)
r	55.40 (20.88)	114.42 (0.62)	137.71 (0.91)	138.25 (2.02)	177.93 (4.05)
LL	252.47	296.42	225.23	259.03	290.34
KS	0.69 (0)	2.15 (1)	1.06 (0)	0.95 (0)	0.82 (0)

Table 2 shows q_i, the fraction of the consumers that search for mortgage rate quotes at *i* banks. The values within the parenthesises are the standard deviations of the estimated fractions. $\underline{I}$ and $\overline{I}$ are the estimated lower and upper bounds of the mortgage rate distribution, N is the number of banks in the sample and M is the number of mortgage quotes. r is the estimated cost of "producing" one average mortgage for the representative bank. LL is the log-likelihood of the models. As a goodness-of-fit test of the models, KS is the Kolmogorov-Smirnov test that is used to evaluate the fit. The test is used to test if the estimated mortgage rate distribution is drawn from the empirical distribution of mortgage rates. The null hypothesis is that they are from the same distribution, and the alternative hypothesis is that they differ. The values are the KS test statistic, and the values within the parenthesis indicate the result from the hypothesis test where 0 indicates the null cannot be rejected and 1 indicates that the null can be rejected. To graphically see the fit of the models, see appendix (2.1 to 2.5).

As the table shows, there are some interesting results from the estimation procedure. One thing that stands out is the for the three-months fixed mortgage rates, roughly 89 % of consumers only search once, i.e. they do not search for mortgage quotes except for their initial "free" search. One problem with the estimates for the three-months contracts is the large standard errors for the estimated fractions. Regarding the KS test, all but the one-year fixed rate mortgages cannot reject the null hypothesis. The reason behind the bad fit for that contract is likely because of some extreme values, both high and low. Meaning that there are observed mortgage rates that are distinctly lower and higher then the bell-shaped cluster for the bulk of the observations, see the histogram in appendix (1.4). This could perhaps be the result from some pricing tactics where very low rates are used to attract new customers, and high to experimenting of extracting profits from high search cost individuals for example.

For the contract lengths other than the three-months contract, the consumers can be divided into two distinct categories. The first category constitutes the majority of consumers that search for at most 1 extra mortgage quote, q_1 and q_2, and a small minority of between 6 to 10 % that search across all banks, q_8. This behaviour is quite interesting that for the financing of ones biggest personal purchase, most people do not search, or only searches at two places. This then conveys a lot of market power to the banks and can have some important implications for the mortgage market.

Although the distribution of consumers that visit 1,2...N banks are interesting. To gain a broader sense of the workings of the consumers' behaviour on the mortgage market, one also needs to consider the critical values that correspond to the cut-off points, which indicates the indifferent consumers "actual" cost of searching. The estimated critical values for the cut-off points for the search cost distribution are summarized in table 3.

Table 3: Critical Search Cost Values

Contract lengths	Three-months	One-year	Two-years	Three-years	Five-years
Δ_1	4.05 (7.21)	8.26 (0.11)	3.46 (0.16)	4.90 (0.21)	7.43 (0.39)
Δ_2	2.07 (3.42)	4.09 (0.01)	1.74 (0.05)	2.25 (0.07)	3.10 (0.31)
Δ_3	1.29 (1.99)	2.52 (0.01)	1.09 (0.02)	1.32 (0.03)	1.72 (0.22)
Δ_4	0.89 (1.30)	1.74 (0.02)	0.76 (0.01)	0.88 (0.02)	1.11 (0.16)
Δ_5	0.66 (0.92)	1.29 (0.02)	0.56 (0.00)	0.64 (0.01)	0.79 (0.12)
Δ_6	0.51 (0.69)	1.00 (0.01)	0.44 (0.00)	0.49 (0.01)	0.59 (0.10)
Δ_7	0.41 (0.53)	0.80 (0.01)	0.35 (0.00)	0.38 (0.01)	0.46 (0.08)

The Δ_i's in table 3 are the estimated critical search costs, with its corresponding standard deviations within the parenthesis. The values are the estimated cost for an individual that is indifferent between searching i and $i + 1$ times. As one can see in the table, the estimated critical search costs for the three month contract has very large standard deviations, which is a remnant from the estimation of the distribution of the fraction of consumers that search different amount of times. As these estimates are not so efficient, the only conclusion that can be had about the three months contract is that there are a considerable amount of consumers that do not search a lot, but their search costs are likely above 4.05 basis points, which is quite low. As table two and three show, for the one-year contract, there are 56 % of the consumers with a search cost above 8.26 basis points, 33 % with costs above 4.09 and below 8.26 basis points and 10 % with a very low search cost of below 0.8 basis points and who searches for mortgage rate quotes at all banks in the market. The other fixed rate mortgage contract lengths can be read in the same way, but the thing that stands out is that the estimated search costs for the two- and three year are considerably lower than for the one- and five year mortgages. The estimated CDF´s of the critical search costs are presented graphically in appendix (3.1 to 3.5).

One dissatisfying aspect of this estimation approach is that one cannot retrieve the closed form estimates of the distribution, i.e. the bounds of the distributions are not defined. In this setting, it poses a problem for quantifying the total frictions in the market since the consumers appear to be divided into two categories, where a large part have high costs and do not search at all, and some have very low costs and search a lot. This then have the implication that for example for the three-year mortgage rate, one only knows that roughly 53 % have a search cost above the critical value of 4.9, but one cannot retrieve the distribution of search costs among those consumers.

Another problem with this approach is that all dispersion of mortgage rates are assumed to stem purely from consumers cost of searching and aspects such as differences in branding and consumer preferences for different banks, will be included as search costs. This is a problem regardless of approach, when assuming homogeneity among products that might not be homogeneous. Another problem is the omission of the switching costs in the market, which can be significant and will end up as search costs in the estimation.

6.5 Search costs in monetary terms

As so far, the units of measurements have been basis points of the yearly mortgage rates of the different contract lengths. Due to the nature of compounding interest rates, comparing a one-year fixed mortgage and a five-year fixed mortgage, just on differences in absolute values of the mortgage rates can be tricky. To convert the critical search cost in basis points to monetary units, I assume that no one switches bank during the time period and that no one considers any payments on their mortgage. The cost can then be expressed as the increase in the debt for the consumer over the contract length and can be calculated by the formula:

$$c_i = \beta(1 + \frac{\Delta_i}{10000})^t - \beta \tag{13}$$

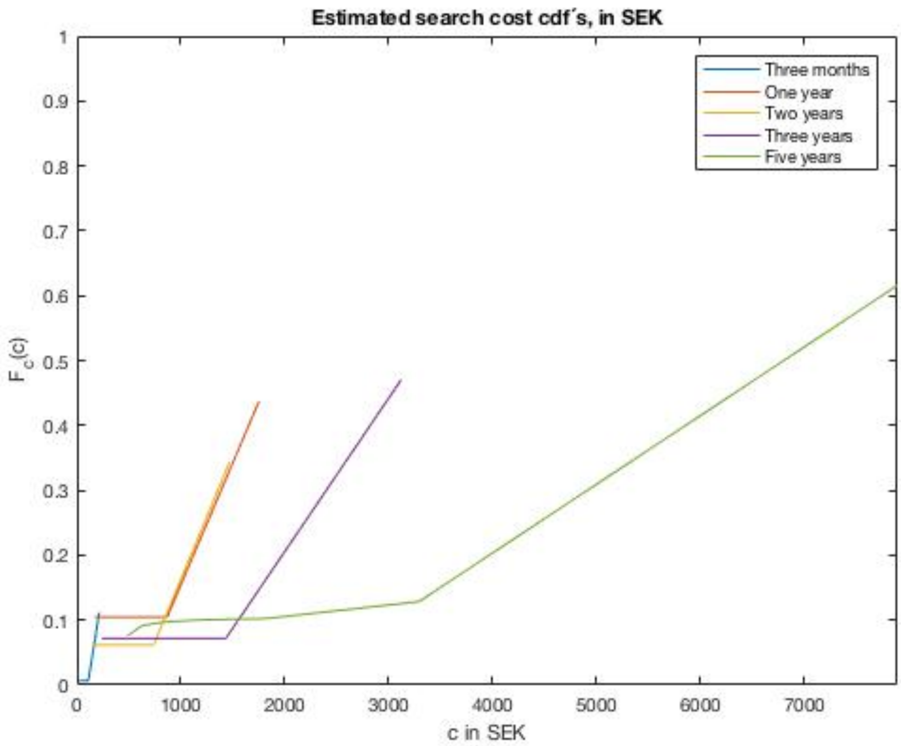
Where c_i is the critical cost in monetary terms, β is the size of the mortgage, Δ_i is the critical search cost values (table 3), and t is the number of years that the mortgage rate is fixed. The converted values are presented in table 4 for the value of the average mortgage of 2 122 680 SEK (Finansinspektionen, 2017).

Table 4: Critical Search Cost Values in SEK

Contract lengths	Three-months	One-year	Two-years	Three-years	Five-years
c_1	214.9 (382.5)	1753.3 (23.4)	1469.2 (67.9)	3121.9 (133.7)	7897.5 (413)
c_2	109.8 (181.5)	868.2 (2.1)	728.8 (21.2)	1433.1 (44.6)	3292.2 (329)
c_3	68.5 (181.5)	534.9 (2.1)	462.8 (8.5)	840.7 (19.1)	1826.1 (233.5)
c_4	47.2 (68)	369.4 (4.3)	322.7 (4.3)	560.4 (12.7)	1178.4 (169.8)
c_5	35 (48.8)	273.8 (4.3)	237.8 (0)	407.6 (6.4)	838.6 (127.4)
c_6	27.1 (36.6)	212.3 (2.1)	186.8 (0)	312.1 (6.4)	626.3 (106.1)
c_7	21.8 (28.1)	169.8 (2.1)	148.6 (0)	241 (6.4)	488.3 (84.9)

As the table above indicates, there are fractions of consumers that have substantial search costs in monetary terms and with the same interpretation as before. The values are in Swedish Kronor, roughly 1/10:th the value of the Euro. This table is quite hard to read the search cost distributions in monetary terms of consumers are presented in figure 1.

Figure 1: Search Cost CDF´s in Monetary Terms



As figure 1 shows, there are some large differences in the search cost CDF's, due to the results from the estimation that there are a lot of consumers that do not search more than once, the lines cut-off early and do not continue up to 1 as a CDF should. As the figure indicates, the lines seem to be quite similar near the lower bounds of the distributions but later diverge. This could be interpreted as that the consumers that search a lot, regardless of contract length on their mortgage, have similar search costs. Unfortunately, one should be cautious when interpreting the results from these estimates, since for the three-months contract, the estimates were very uncertain and the fit-measure of the model rejected the one-year contract. Focusing the analysis on only the three remaining contracts, one trend that shows is that the search cost distribution increases with the length of the mortgage, at least for the bottom half of the distributions.

6.6 Robustness Check

As there might be a problem of omitted banks in the data, the results from this estimation procedure could yield a downward bias of the estimated search cost distribution. Adding to this bias, the fraction of consumers that do not search at all, can exhibit a positive bias (Moraga-González & Wildenbeest, 2008).

As a robustness check, I will drop the smaller banks in my sample and re-run the estimation procedure to see if the market behaves in the same way. The reason behind this is that the Swedish mortgage market is characterized by a small amount of banks with considerable market shares. I will drop Skandiabanken, Danske Bank and Länsförsäkringar Bank, which leave five banks. Due to this fact, I will not be able to estimates the same set of estimates as I can only retrieve four cut-off points, but the general workings of the estimated markets can still be compared.

The results corresponding to the earlier estimates in table 2 and 3 are presented in table 5 and 6.

Table 5: Search Cost Distributions, Five Biggest Banks

Contract lengths	Three-months	One-year	Two-years	Three-years	Five-years
$\underline{I}$	149	146	152	151	189
$\bar{I}$	168	175	175	181	242
N	5	5	5	5	5
M	50	50	46	50	50
q_1	0.86 (0.20)	0.87 (0.01)	0.89 (0.09)	0.73 (0.03)	0.50 (0.22)
q_2	0.13 (0.17)	0.11 (0.02)	0.12 (0.07)	0.24 (0.04)	0.44 (0.10)
q_3	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
q_4	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
q_5	0.01 (0.04)	0.02 (0.00)	0.02 (0.02)	0.03 (0.01)	0.06 (0.14)
r	98.27 (15.95)	67.98 (1.90)	94.38 (7.96)	115.84 (2.13)	166.10 (11.61)
LL	137.86	158.77	135.84	155.35	181.21
KS	0.74 (0)	1.68 (1)	1.22 (0)	1.14 (0)	0.94 (0)

These estimates in the robustness test indicate that the earlier estimates follow the same pattern. Namely that the estimates for the q_i´s for the three months mortgage rate are relatively uncertain and that the Kolmogorov-Smirnov test statistic for the one-year mortgage is significant and rejects the null hypothesis that the estimated mortgage rate distribution fits the empirical distribution.

As expected, the fractions of consumers that do not search seem to be higher in the robustness test, likely due to the bias described in Moraga-González & Wildenbeest (2008) when omitting firms. Other than these changes, the estimated search behaviour does not change drastically when omitting the smaller banks, which could be interpreted that the model specifications, assumptions about the market behaviour and estimation procedure follows the markets real behaviour quite well.

Table 6: Critical Search Cost Values, Five Biggest Banks

Contract lengths	Three-months	One-year	Two-years	Three-years	Five-years
Δ_1	3.07 (4.74)	4.65 (0.72)	3.69 (2.17)	4.83 (0.58)	8.05 (0.95)
Δ_2	1.56 (2.02)	2.43 (0.34)	1.93 (1.01)	2.33 (0.24)	3.42 (0.49)
Δ_3	0.95 (1.26)	1.52 (0.19)	1.20 (0.58)	1.38 (0.12)	1.87 (0.30)
Δ_4	0.64 (0.81)	1.05 (0.12)	0.83 (0.37)	0.91 (0.07)	1.18 (0.20)

The estimated critical search cost values when omitting the three banks is also following a similar pattern as the original model with a minority that search a lot, and a majority that search very little.

To summarize the robustness test, there are no indications that the estimated workings of the mortgage market change drastically when only considering the biggest five banks in the market. As the estimates follow the expected value change and the fact that I omit small banks in my original analysis, there is a chance that my estimated fractions are biased towards fewer searches in the market. This is an important aspect to consider when drawing conclusions from the analysis. I also did a robustness check where I randomly draw five banks instead of as previously, just the five largest. The results can be seen in appendix (7) and follows the same pattern as here.

6.7 Summary of results

To answer the question stated in the beginning of the paper, "can the observed distribution of mortgage rates be the result of costly consumer search?" the answer is two-folded.

Firstly, the three-months and one-year contracts had some issues. Regarding the three-months fixed mortgage rates, the estimated model has very large standard errors and thus one should be cautious about the results, even if the model fit was good. Given that the data has problematic properties for that contract length, it is likely that there are other factors that drive the dispersion of three-months mortgage rates such as differences in the banks cost structures, etc. Although, since the contract length is so short and the gains from switching is quite small.

Given this, it is not so hard to think that almost nobody searches for mortgages every three-months and thus the model might fit reality quite well. For the one-year mortgage rates, the fit of the model was rejected and the consumer search model in this analysis are perhaps not the best description of the mortgage pricing behaviour for this contract length. Other factors are then partly or fully responsible for the observed mortgages, for example differences in costs or tactical pricing.

Secondly, for the two-year, three-year and five-year mortgage rates; the models seem to fit well with the observed mortgage rates and assumed behaviour. The three estimated models show similar consumer behaviour where consumers can be divided into a majority that searches either at one or two banks and a minority that searches across all banks in the market. The search costs for consumers that take out a five-year fixed mortgage are fairly larger than the other two in monetary terms. The reason behind this could be manifold and would need further research. One possible explanation is the fact that consumers that select into longer mortgage rate contracts are more risk adverse (Cambell & Joao F., 2003), which in turn makes it more "costly" for them to take the risk of sampling another bank. There is also the problem with self-selection in Sweden of consumers with different personal characteristics into different mortgage contracts (see Hullgren & Söderberg (2016) and (2013)), which could affect the results. Another possible explanation could be that consumers are not so financially literate and experience difficulties to realize the compounding nature of interest rates. Thus, they do not calculate the expected savings from switching correctly (Lusardi & Mitchell, 2011). Behind this could also be several behavioural biases, such as for example money illusion, which can have strong effects on consumer behaviour (Eldar et al., 1997).

7. Simulations of changes in the parameters

7.1 Effects from a cost increase

One interesting aspect, which this modelling approach facilitates, is the possibility to simulate the effects of a change in the parameters. In this section, I will simulate the effects of an increase in the banks costs, in the form of an increase in an independent cost component that the banks face, to see how it transfers over to the consumers. The effects that I am interested in are the distribution of mortgage rates and its response to changes in banks costs. To model this, I rewrite equation (4) by adding t as a cost for the banks as:

$$(\mathrm{I} - \mathrm{r} - \mathrm{t})\left[\sum_{\mathrm{i}=1}^{\mathrm{N}} \frac{\mathrm{iq_i}}{\mathrm{N}}\left(1 - \mathrm{F_I}(\mathrm{I})\right)^{\mathrm{i}-1}\right] = \frac{\mathrm{q_1}\left(\bar{\mathrm{I}} - \mathrm{r} - \mathrm{t}\right)}{\mathrm{N}} \tag{14}$$

As $\bar{I}$ is assumed to be the consumers' reservation "price", a change in the banks cost would not change the consumers' valuation of a mortgage. Just looking at the equation above, the total effects of an increase in the banks costs are not obvious. To see what happens at the lower bound of the mortgage rate distribution, $\underline{I}$ can be written as:

$$\underline{I} = \frac{q_1(\bar{I} - r - t)}{\sum_{i=1}^{N} iq_i} + r + t \tag{15}$$

Comparing the lower bound with (right hand side) and without (left hand side) the added cost t yields inequality (16).

$$\frac{q_1(\bar{I} - r)}{\sum_{i=1}^{N} iq_i} + r \leq \frac{q_1(\bar{I} - r - t)}{\sum_{i=1}^{N} iq_i} + r + t \tag{16}$$

Which simplifies to

$$q_1 \leq \sum_{i=1}^{N} iq_i \tag{17}$$

One can see that as long as there are at least some consumers that are searching and if t is strictly positive the inequality (17) holds[8]. This then implies that an increase in costs, compresses the distribution of mortgage rates, holding the upper bound constant.

Due to the fact that $q_i's$ have to sum to one, if N = 1, this inequality becomes an equality. If $N > 1$ when $q_1 < 1$, the expression becomes an strict inequality. This implies that if there are only one firm or if no one searches, adding t does not affect the lower bound of the mortgage rate distribution. This makes sense since in that case, all banks will set the rates at the consumers reservation "price" which is not affected by cost increases for the banks. But in the case where there is a strict inequality, an increase in the cost for banks will raise the lower bound. Simulating theses effects in the context for the five year mortgage rate will be presented in this section, as in this case, $N > 1$ and $q_1 < 1$, the expected effects are that the mortgage rate distribution will be compressed and the lower bound raised.

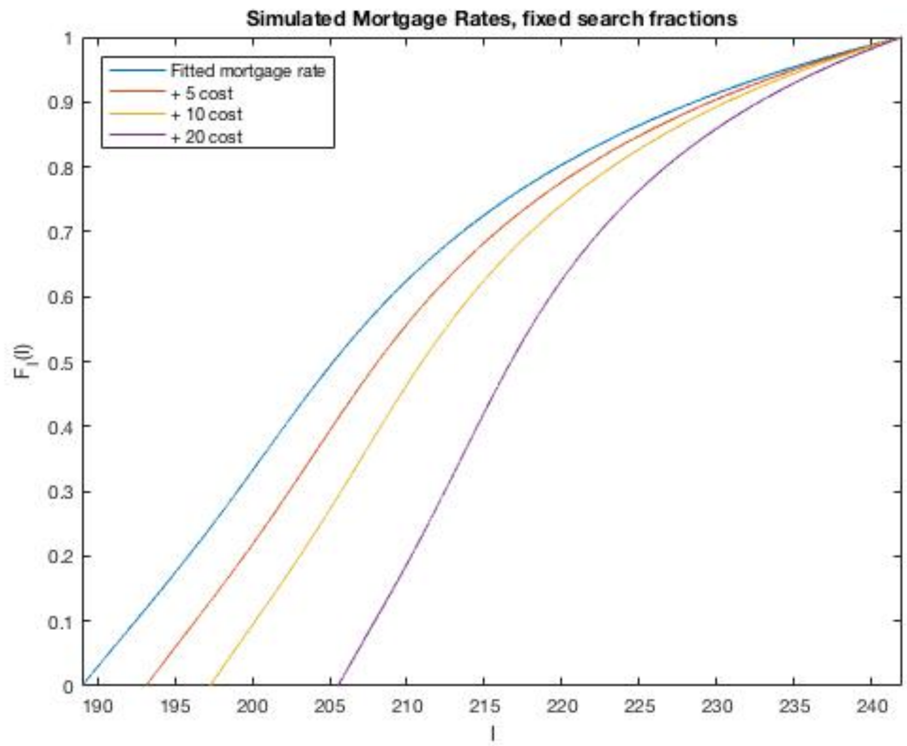
[8] If instead t is negative, the inequality does not hold and the lower bound would decrease.

To simulate the mortgage rate distribution, I need to first approximate the search cost distribution with a continuous function to make it possible to retrieve new cut-off point's Δ_i that are later used to construct the q_i´s. I fitted a polynomial of degree 3 to the estimated cut-off points (appendix 4.1) with the functional form of[9]:

$$\hat{f}(x) = 0.002859x^3 - 0.01457x^2 + 0.2018x + 0.09586 \tag{18}$$

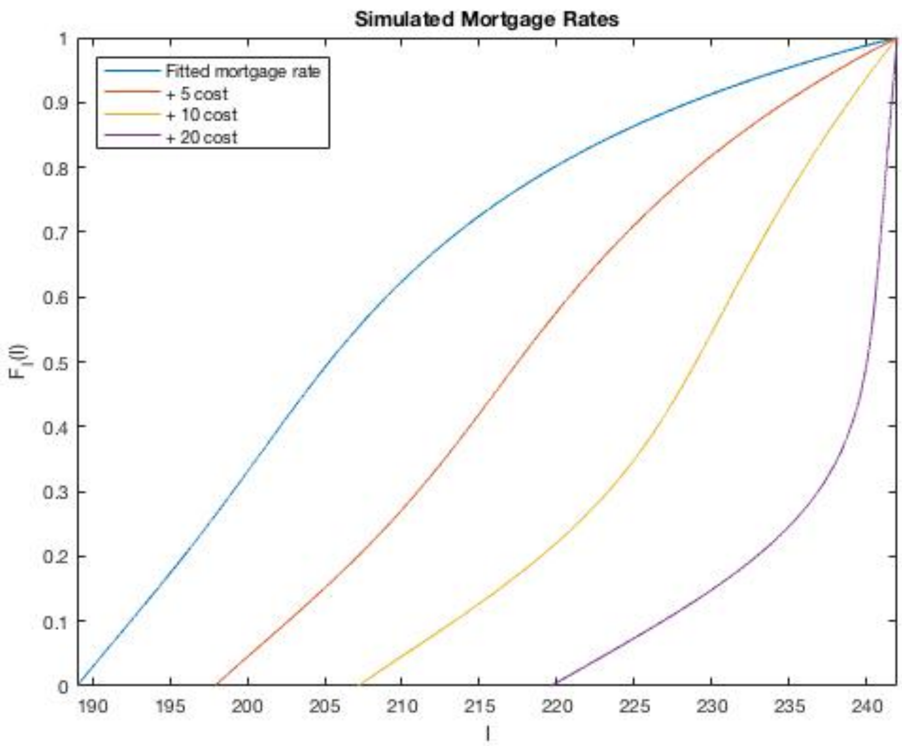
Then, using the equations I set up in the theoretical framework, one can then solve for the desired parameters and mortgage rate distributions numerically. Simulating the effects from the arbitrarily chosen cost increases of 5, 10 and 20 basis points for the cost of banks to provide an average mortgage are presented below. If one holds the fractions of consumers that searches i times constant, the change in the distribution can be seen in figure (3a). But since in equilibrium, the gains from searching changes, and thus the consumer behaviour needs to change. Simulating the effects when taking this into account, the resulting mortgage rate distributions are presented in figure (3b).

Figure 3a



[9] There is no specific reason to fit a polynomial to the cut-off points and any smooth function would do. The reason that I chose a polynomial is that it fitted the cut-off points well with an Adj. R^2 of 1. Given its convenient functional form and fit within the set of values of my interest, I believe it is a good choice.

Figure 3b:



The simulated parameters of the models are presented in table 7.

Table 7: Simulation results

Model	Estimated	Fitted	+ 5 points cost	+ 10 points cost	+ 20 points cost
$\underline{I}$	189	189	197.89	207.14	219.63
$\bar{I}$	242	242	242	242	242
q_1	0.39 (0.13)	0.385	0.529	0.686	0.864
q_2	0.51 (0.06)	0.512	0.37	0.212	0.0363
$q_3 \rightarrow q_7$	0.00 (0.00)	0.00	0.00	0.00	0.00
q_8	0.10 (0.10)	0.103	0.102	0.103	0.103
r	177.93 (4.02)	177.93	177.93	177.93	177.93
$\mathbb{E}[I]$	207.5 (11.7)	208.03	218.15 (+4.86%)	227.57 (+9.39%)	237.15 (+14%)
$\mathbb{E}[I] fixed\ q_i$	-	208.03	210.68	213.33	218.63

Table 7 is read as before where q_i´s are the respective fractions that search *i* times. $\underline{I}$ and $\bar{I}$ are the lower and upper bounds of the mortgage rate distributions, *r* is the estimated cost and $\mathbb{E}[I]$ is the expected value of the respective price distributions. In the first column, the values in the parenthesis are standard errors and the values in the parenthesis on the last row and second to forth column are the change in expected value of the mortgage rate distributions when adding a cost, compared to the fitted model. The estimated values for q_3 to q_7 are all approximately zero for all models, and are thus compressed into one row. The simulated cut-off points are presented in table 8.

Table 8: Simulated Cut-off Points

Model	Estimated	Fitted	+ 5 points cost	+ 10 points cost	+ 20 points cost
Δ_1	7.43 (0.39)	7.4341	6.8582	6.0240	4.2166
Δ_2	3.10 (0.31)	3.0977	2.8608	2.8819	2.3577
Δ_3	1.72 (0.22)	1.7224	1.5918	1.7417	1.5672
Δ_4	1.11 (0.16)	1.1144	1.0304	1.1884	1.1370
Δ_5	0.79 (0.12)	0.7883	0.7291	0.8713	0.8693
Δ_6	0.59 (0.10)	0.5908	0.5465	0.6697	0.6885
Δ_7	0.46 (0.08)	0.4609	0.4264	0.5322	0.5595

As expected, when adding a cost to the banks, the lower bound of the mortgage rate distributions increased. This then led to fewer searches in the market, since the expected gains decreased and holding search costs constant, less consumers will find it worthwhile to search and thus more market power are given to the banks. One interesting aspect when comparing the mortgage rate distributions when consumers change their behaviour, and when they do not, are that there are huge differences between the pricing of the mortgages. Comparing figure 3a to 3b, one can see that the respective distributions are pushed rightward when consumer behaviour is taken into account, indicating that the average mortgage rates increase not only because the banks cost of "producing" a mortgage increased, but also through the fact that consumers give more market power to the banks through less search. In the simulations, the fractions of consumers that do not search for more than their initial "free" mortgage rate quote, goes from around 39% to 86% which is an substantial amount of consumers that do not think it is worthwhile to try to get a cheaper mortgage.

The reason for these strong effects is because of the "steep" curve that is fitted to the cut-off points (appendix 5). Since the curve is steep, even small differences in the expected minimum of visiting *i* banks have large effects. For example the initial value for the cut-off point for those that are indifferent between going to two banks or one is 7.4341 and adding the cost of 5 results in the corresponding value of 6.8582 a difference in 0.5758, which is a decrease in the expected saving for searching two times instead of once of only 0.005758 percentage points. Still this makes the fraction q_1 to go from 0.385 to 0.529, this sensitivity of the estimated distribution is thus the reason for the quite extreme responses in my simulations. Although my results seem quite extreme, the mortgage market do experience extreme changes in its margins as stated in the introduction where banks average margins have increased from 20 to 173 basis points since 2009 to 2016. This then indicates that there might be some validity in my simulated results.

One important aspect to note in this framework is the absence of wealth effects. Since I assume that the distribution of search costs are fixed in the economy and that it do not change when the costs are added. As the expected mortgage rate rise, the wealth of the consumers decreases. This then could affect the search behaviour of the consumers, but it is not possible to retrieve these effects in this framework. This then implies that one should not put too much weight on the exact quantitative results from the simulations, but instead regard the qualitative results.

7.2 Change in consumers search costs

Changing the search costs for consumers, are quite abstract in this setting. Since I cannot estimate the full distribution of all consumers search cost, changing the search profile across all consumers in a precise manner is dubious at best.

In this section I will take a more qualitative approach to analyse what would happen to the distribution of mortgage rates if the fractions of consumers with high search cost decreases, lowering the total search costs in the market. To do this, I have re-parameterized the polynomial in equation (18) by increasing the third term by 0.1 to have a steeper curve and turn the curve anti-clockwise which can be seen in appendix (4.2) and the new polynomial has the form:

$$\hat{f}(x) = 0.002859x^3 - 0.01457x^2 + 0.3018x + 0.09586 \qquad (19)$$

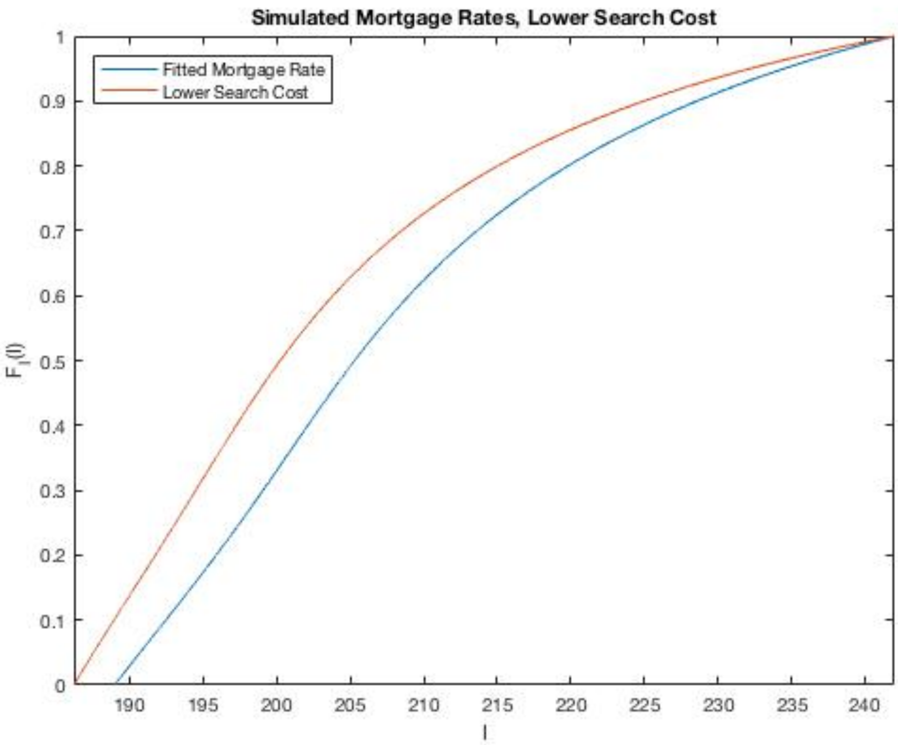
Simulating the effects from the change of the search cost distribution can be seen in table 9.

Table 9: Change in Consumer Search Cost Distribution

Simulated parameters	Fitted	Lower Search Cost	Critical Search Costs	Fitted	Lower Search Cost
$\underline{I}$	189	186.22	Δ_1	7.4341	7.4577
$\bar{I}$	242	242	Δ_2	3.0977	2.9104
q_1	0.3854	0.3036	Δ_3	1.7224	1.5557
q_2	0.5119	0.5657	Δ_4	1.1144	0.9809
q_3	0.00	0.0125	Δ_5	0.7883	0.6813
$q_4 \to q_7$	0.00	0.00	Δ_6	0.5908	0.5037
q_8	0.1027	0.1056	Δ_7	0.4609	0.3888
r	177.93	177.93			
$\mathbb{E}[I]$	208.03	203.75 (-2.1%)			

To see the effects that a change in the search cost has on the distributions of mortgage rates, see figure 4.

Figure 4. Fitted mortgage rate and simulated with lower search costs



As table 9 and figure 4 shows that if the search costs among consumers decrease, the amount of searches in the market increases and the average mortgage rates decrease. As the change in search costs where arbitrarily chosen, one should not draw any quantitative conclusions from these results. Rather, one should take away the result that if the search costs goes down and the fractions of consumer that search increases, the expected results are that the average mortgage rate in the market decreases. These results should be expected since increased search intensity takes away market power from the firms and the banks need to compete more.

8. Conclusions

To conclude this analysis, the consumer search cost framework set up in this paper, succeeds to explain the behaviour of mortgage pricing for some contract lengths but fails for others. Due to the fact that the estimated fractions of consumers that search for a three-months contract are relatively uncertain along with the not so well behaving data, I cannot infer any strong conclusions about that contract length. For the one-year mortgage contract, the fit measure was rejected so purely search cost arguments cannot explain the observed behaviour. To answer the question of what drives the pricing of these contracts, further research is required. One likely explanation to the observed extreme values in the one-year contracts that yield these results could be the result of market tactics to attract consumers during “sales”, and then when they are up for re-setting the mortgage rate, the relative mortgage compared to the banks competitors are not longer so favourable. The search and/or switching costs faced then are too high for the consumer to change bank. This could be a possible route for further research to examine banks tactical pricing over time.

The estimated search cost model fits well for the remaining three different contract lengths and I do believe that search costs are one of the main factors behind the distribution of mortgage rates among banks. But cautions are needed when drawing conclusions from this estimation framework. Since this model assumes that all differences are a result of costly consumer search, differences among banks along dimensions such as cost structure, branding, product differences etc. will end up as consumer search cost regardless of origin. Controlling for this requires a much more detailed data set and indicates an interesting direction for further research to explore the mortgage market in a more nuanced way.

Although the results from the simulation should be interpreted with caution, there are some important policy implications to consider regarding the mortgage market when considering consumer behaviour and search costs. The most important conclusion for this analysis is that if the policy maker thinks that the banks are making too large profits, increasing the costs for the banks could yield the opposite effect. As my simulation results show, increasing the banks costs just a little, yields a larger increase in the expected mortgage rate when considering that consumer search less in a more compact mortgage rate distribution. This then results in larger profits for the banks thanks to consumers that search less.

Given the estimated situation on the mortgage market, and assuming that it describes reality reasonably well. If the policy maker thinks that banks have too large profits from mortgages, increasing consumer search in the market would yield the sought after result. Two possible ways that I think could work on the Swedish mortgage market are to force banks to offer some standardized mortgage products and making switching banks easier, which could be efficient tools. According to Grubb (2015), consumers have problems comparing prices and there are in the interest of the firms to confuse consumers. In this setting making standardized products across banks could help. On the point of making it easier for consumers to switch banks one could imagine that there are many ways of accomplishing it through new technology.

Although, one should be cautious when deriving dynamical properties from static games, given the simulated models, one can be tempted into considering the possible dynamic effects. As figure 3a shows, when the consumers keep their search behaviour constant, the effects are modest. As they learn about the new distribution of mortgage rates and the banks act accordingly, the effects are strong (figure 3b). Translating the search behaviour models regarding mortgage rates and their distributions to a dynamic setting would be a very interesting way forward when analysing the mortgage market. To be able to explain the speed of adjustment to changing fundamentals of the mortgage market could potentially have important policy implications. See for example Hehenkamp's (2002) evolutionary approach to sluggish consumers in a Bertrand setting as a possible starting point. This is an interesting thought for future research, which could have broad applicability to other Bertrand markets.

By making it easier for consumers to compare mortgages and to switch more easily between banks, the search in the market should increase and the banks market power and profits should go down as well according to my simulations. Consumers would receive savings in the form of lower mortgage rates and the competition would increase. But given the scope of this analysis, before starting any interventions more research is needed.

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Varian, H. R. (1992). *Microeconomic Analysis* (3 ed.). New York: Norton & Company, Inc.

10. Data sources

Downloaded 2017-04-04

Danske Bank:

https://danskebank.se/privat/produkter/bolan/relaterat/aktuella-bolanerantor

Handelsbanken:

http://www.handelsbanken.se/shb/INeT/ICentSv.nsf/Default/q326B7B5152FC20CDC1257DEA004CFDCD?OpenDocument&frame=0#

Länsförsäkringar Bank:

https://www.lansforsakringar.se/osfiles/00000-bolanerantor-genomsnittliga.pdf

Nordea:

https://www.nordea.se/privat/aktuella-priser-och-rantor.html?WT.srch=1&mc_en=google&mc_cam=Brand%20+%20Mortgage%20+%20Rate%20-%20Sweden%20-

SBAB:

https://www.sbab.se/1/privat/vara_rantor.html#/rantor

SEB:

https://seb.se/privat/lana/bolan-och-rantor/bolanerantor/genomsnittsrantor-historik

Skandiabanken:

https://www.skandia.se/lana/bolan/historisk-genomsnittsranta/

Swedbank:

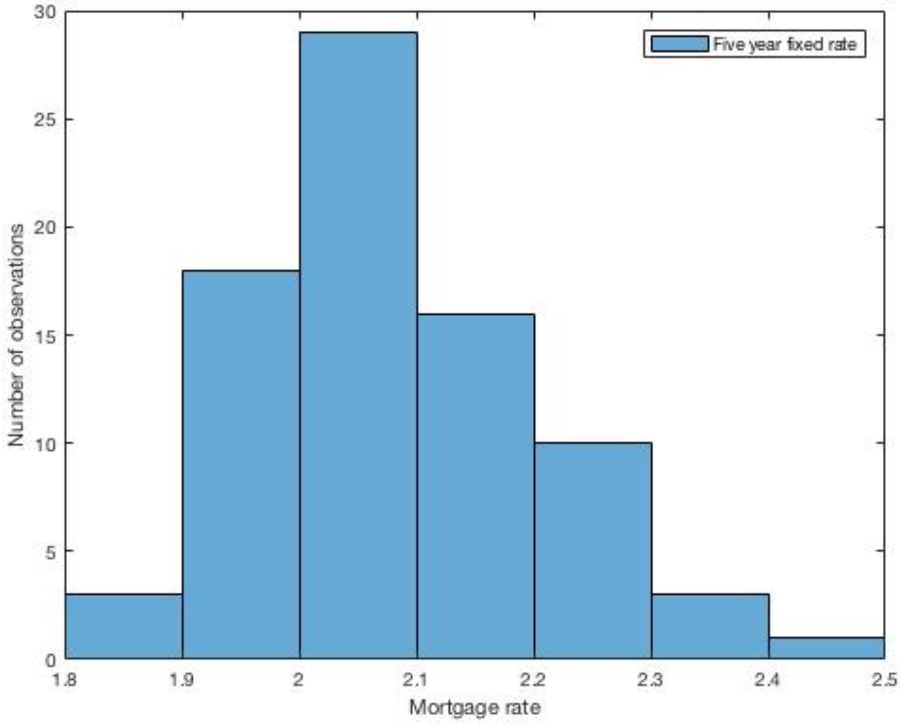
https://www.swedbank.se/privat/rantor-priser-och-kurser/bolanerantor/#!/CID_1737962

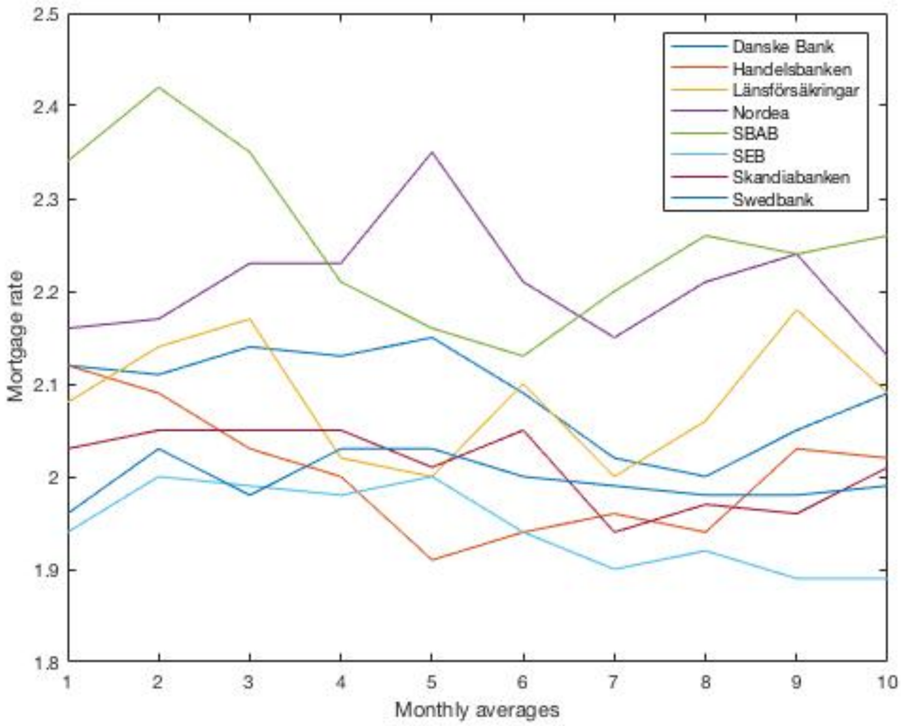
Appendix

1. Data of average monthly mortgage rates

1.1 Five-year contracts:

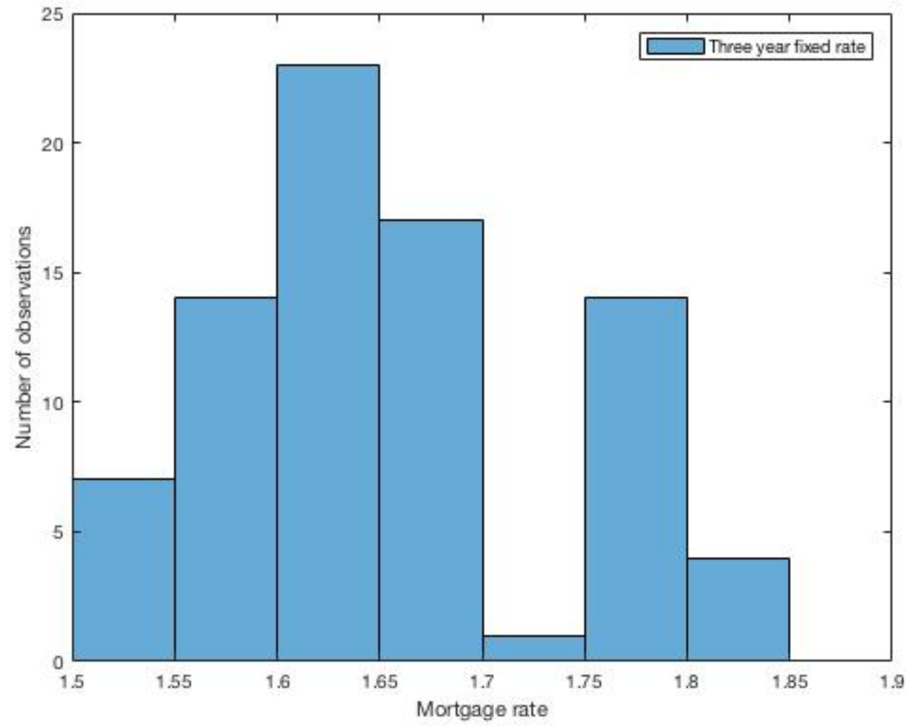
Histogram and over time:

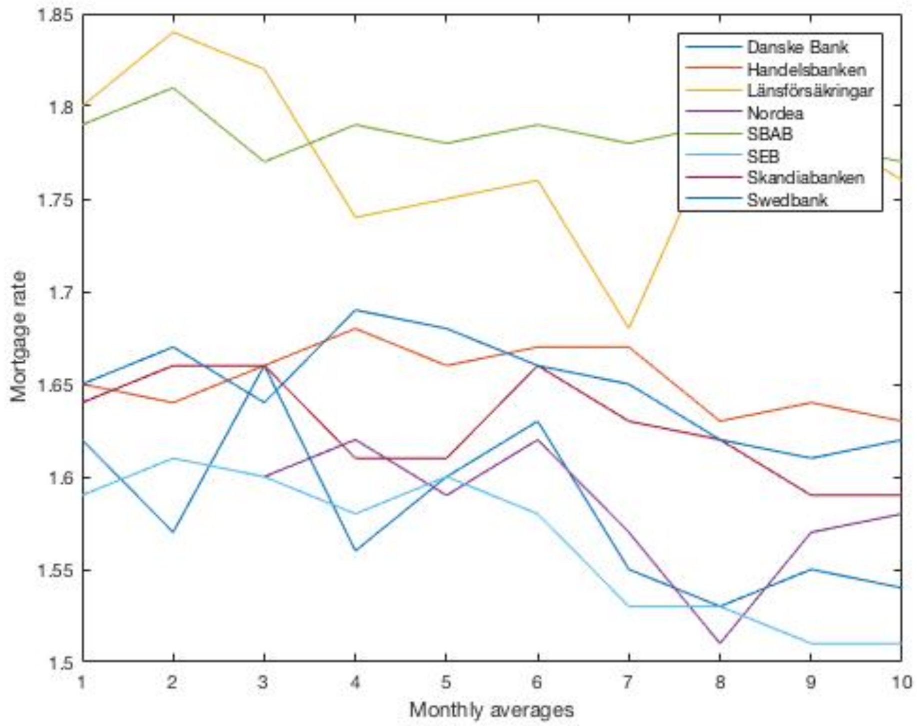




1.2 Three-year contracts:

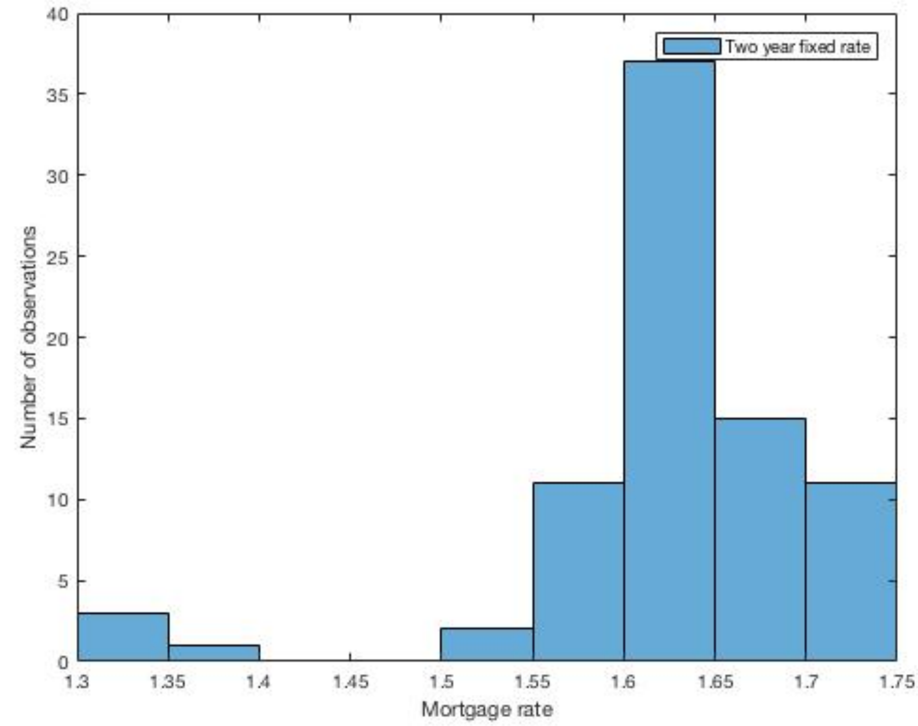
Histogram and over time:

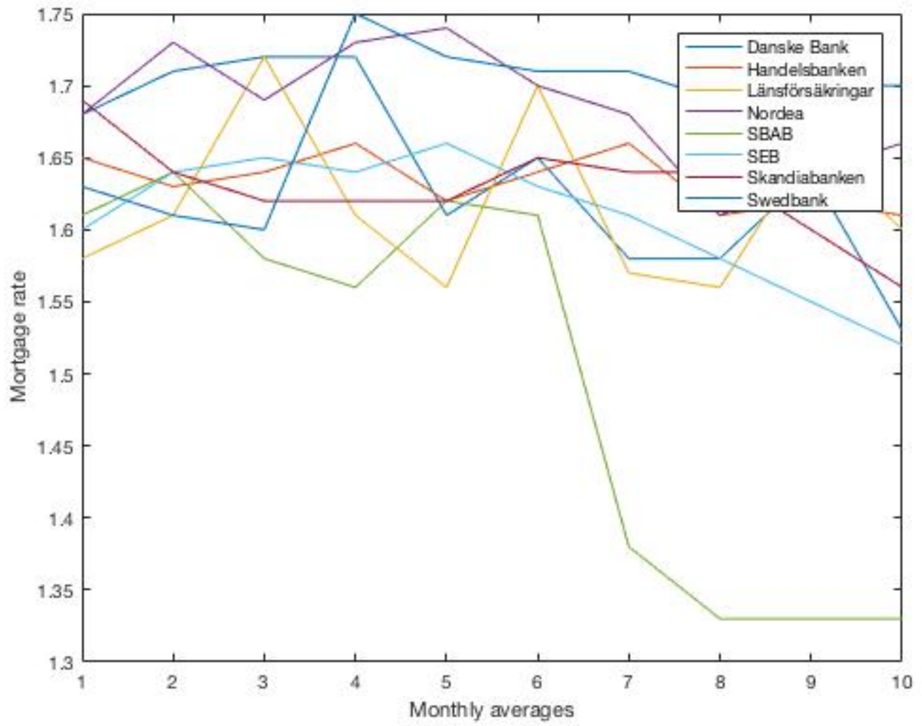




1.3 Two-year contracts:

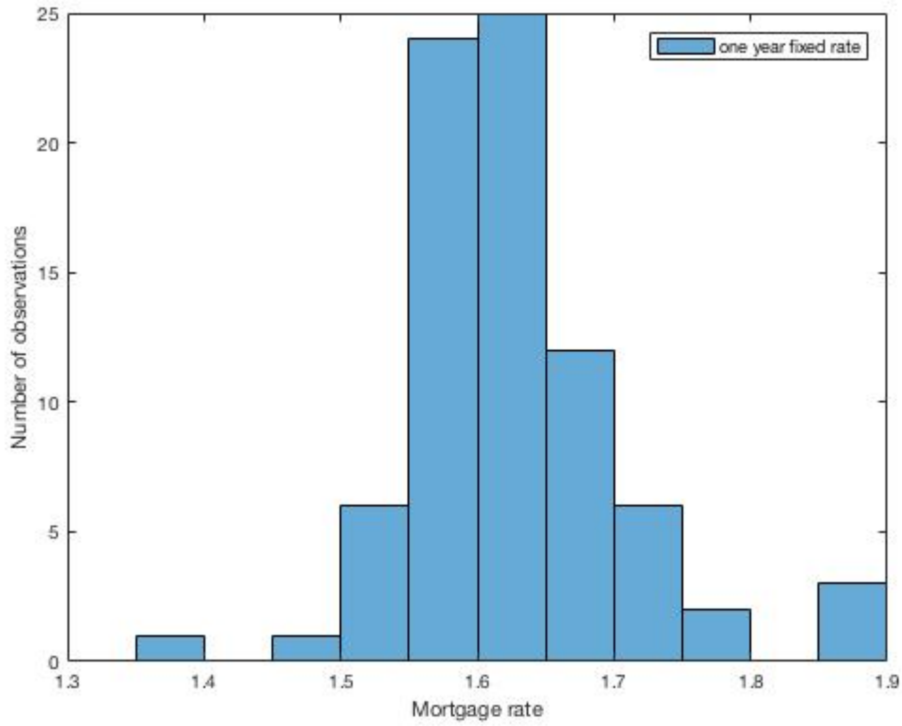
Histogram and over time:

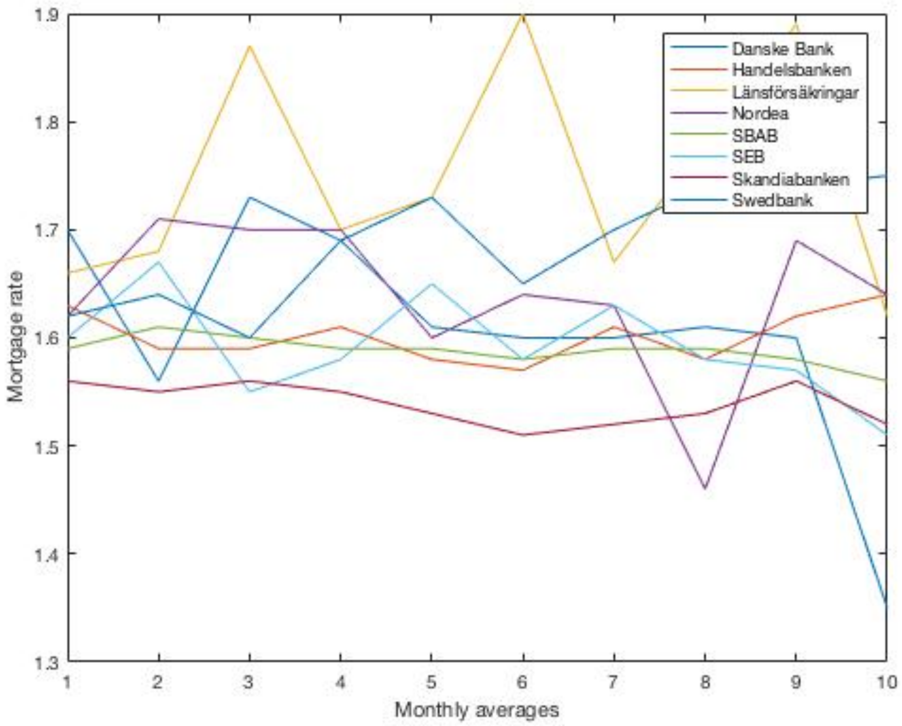




1.4 One-year contract:

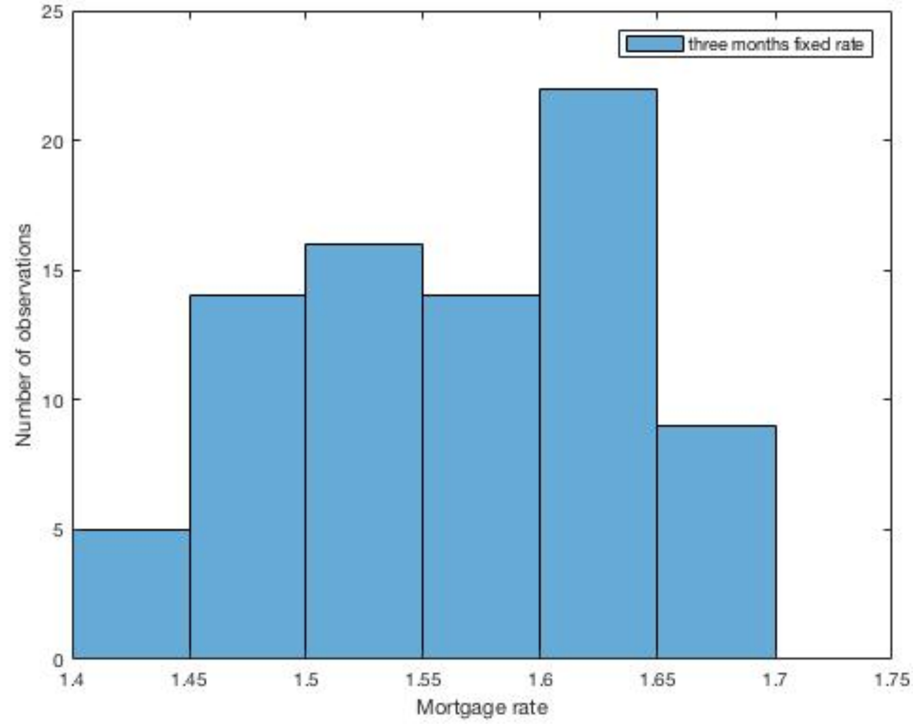
Histogram and over time:

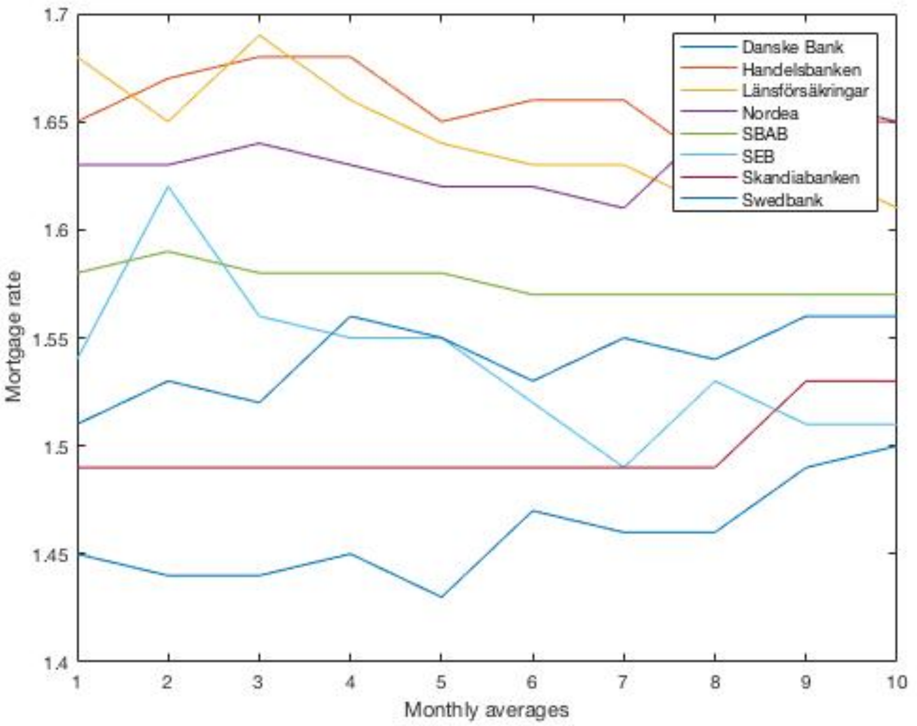




1.5 3-months contracts:

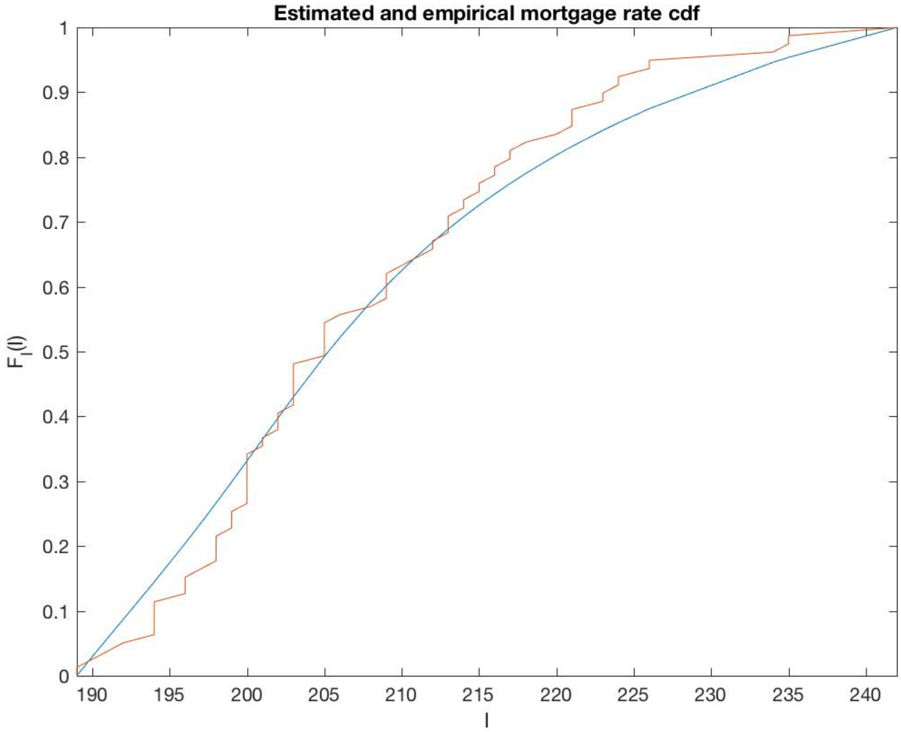
Histogram and over time:



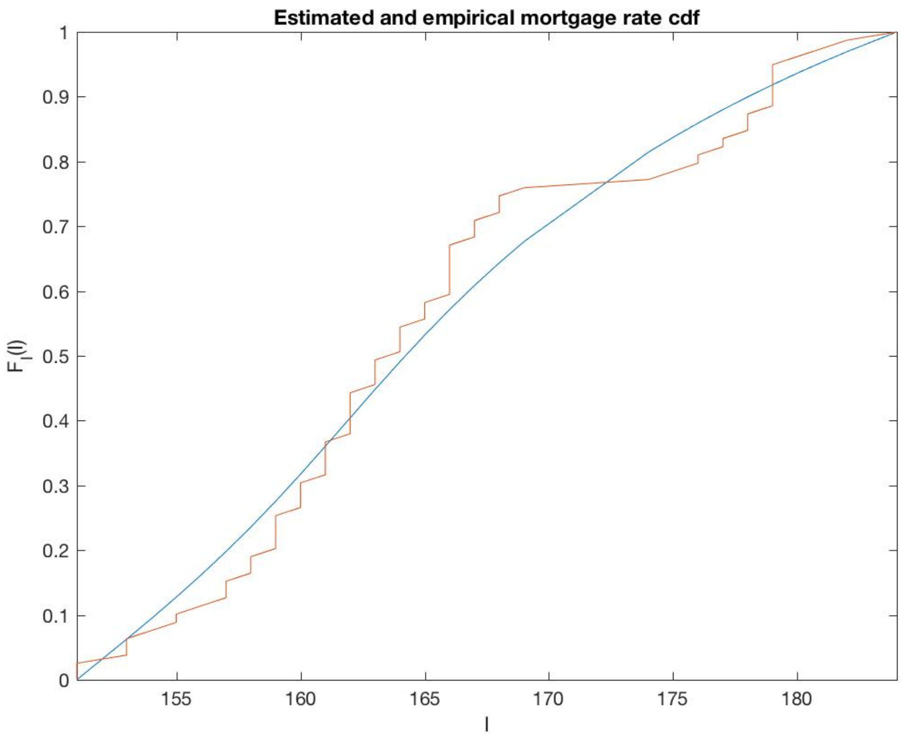


2. Mortgage rate distributions

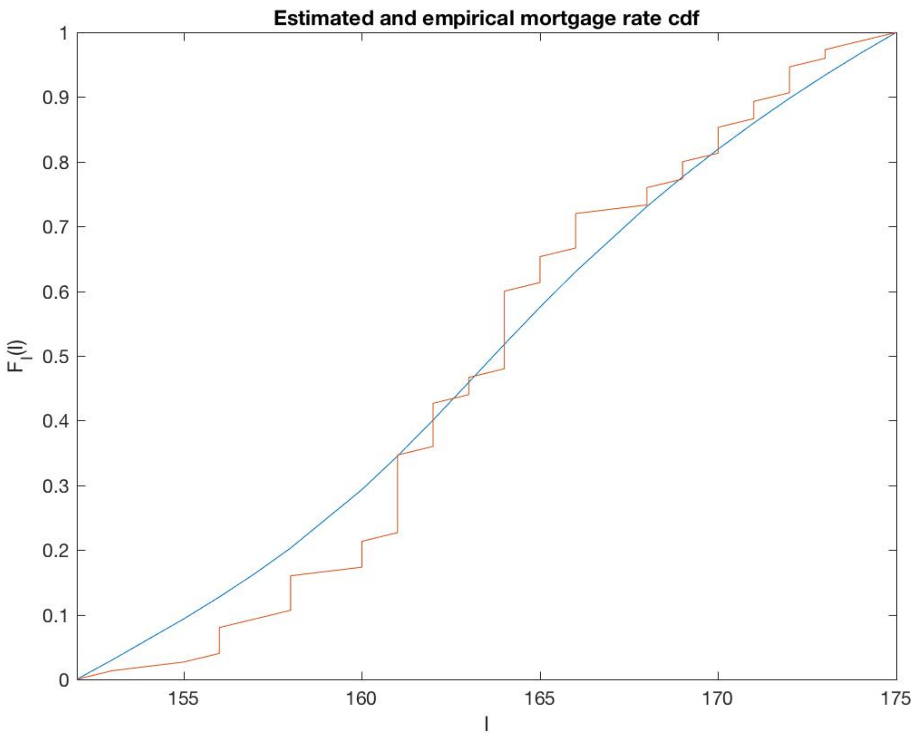
2.1 Five-year



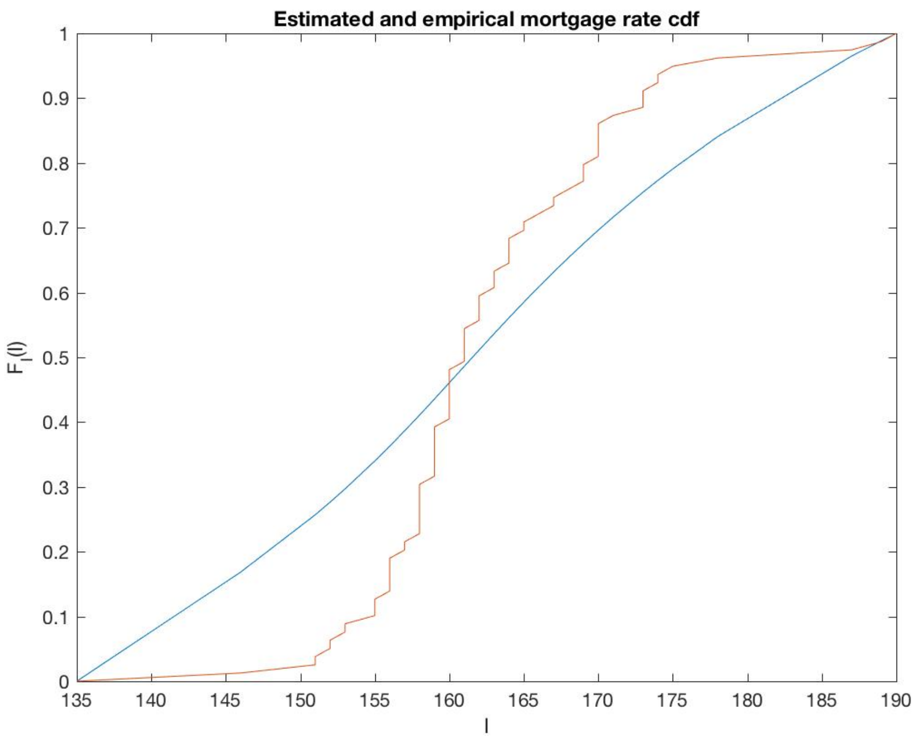
2.2 Three-year



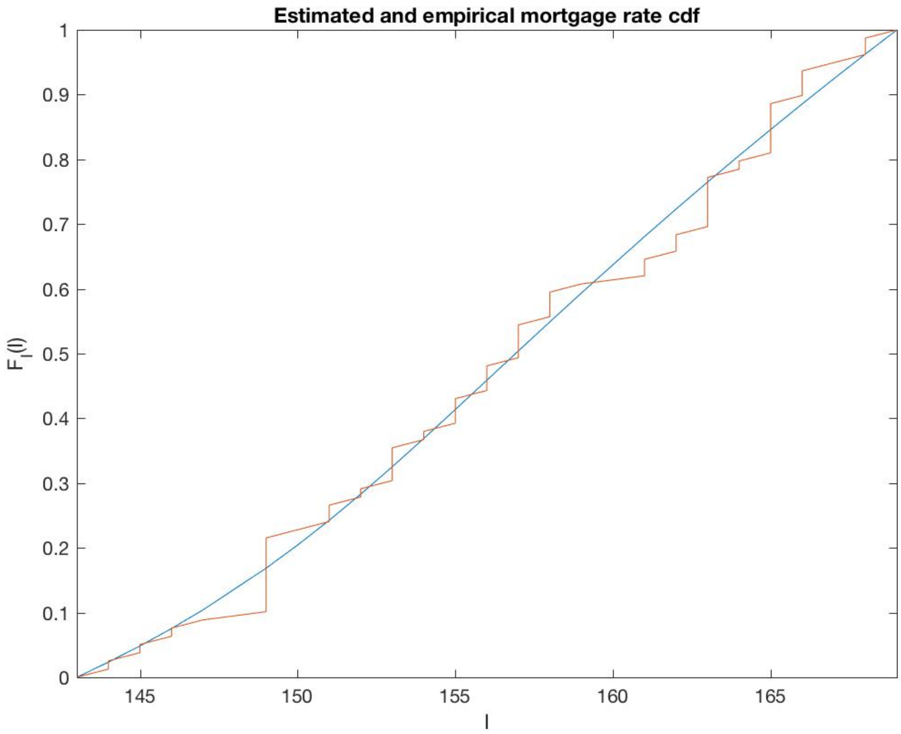
2.3 Two-year



2.4 One-year

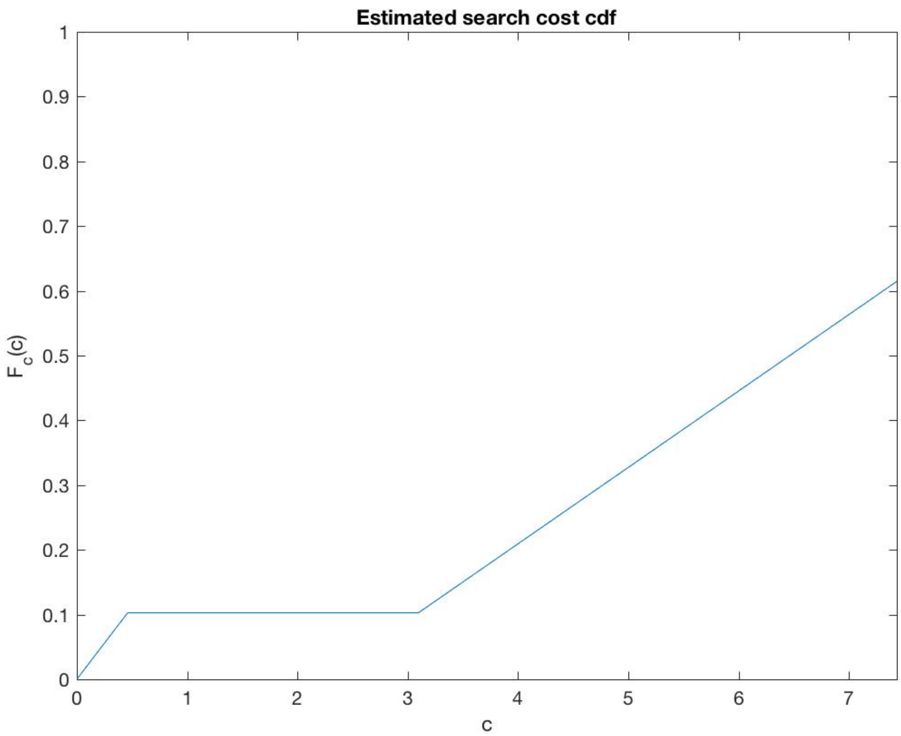


2.5 Three-months

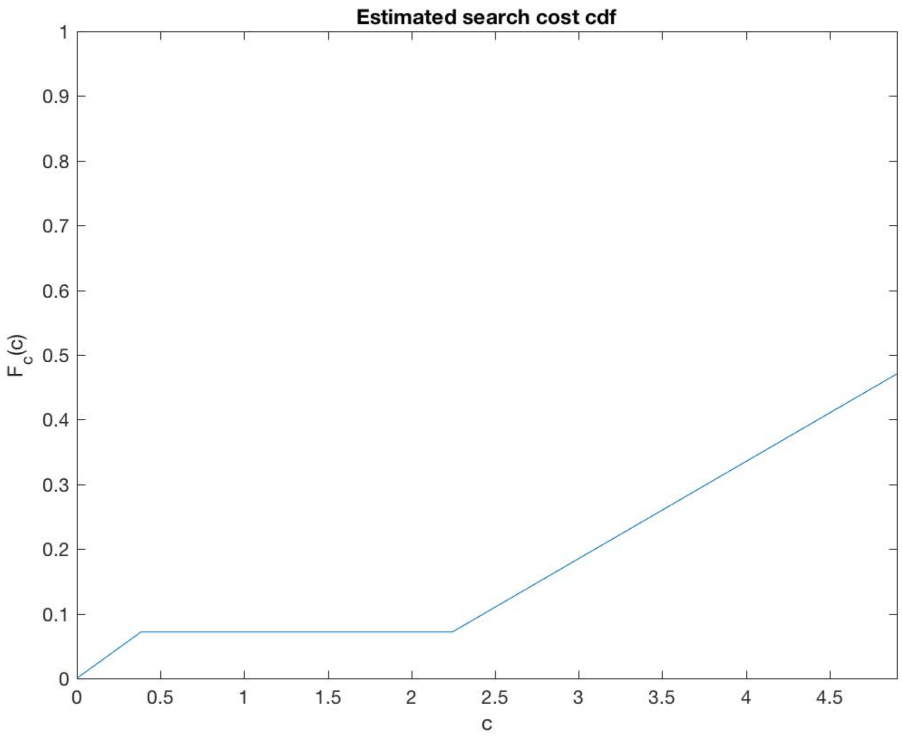


3. Search Cost Distributions

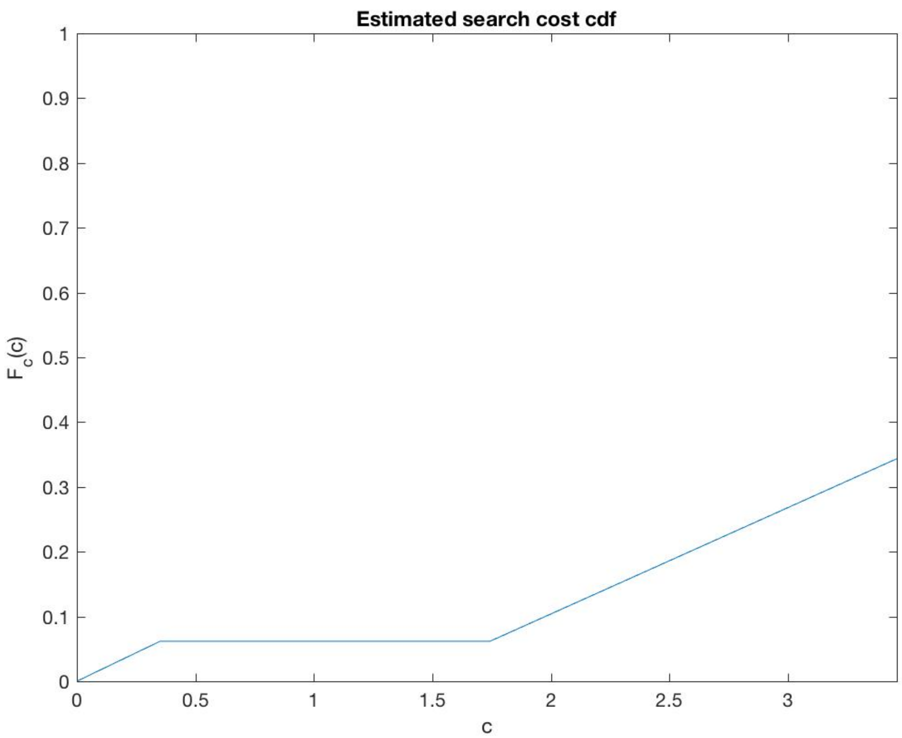
3.1 Five-year



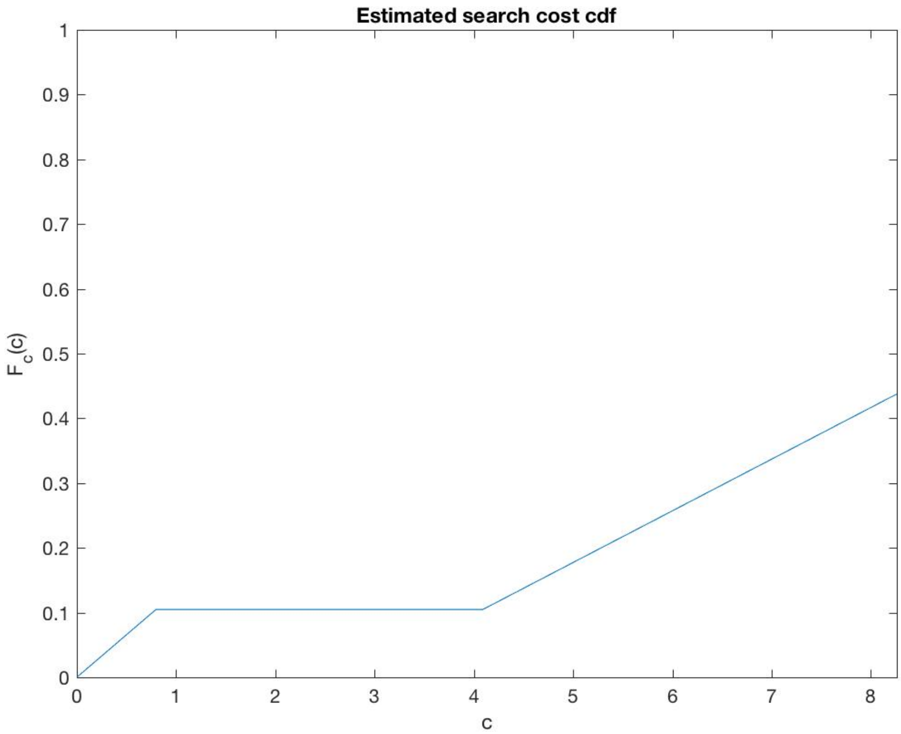
3.2 Three-year


Estimated search cost cdf
$F_c(c)$
c
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.5
1
1.5
2
2.5
3
3.5
4
4.5

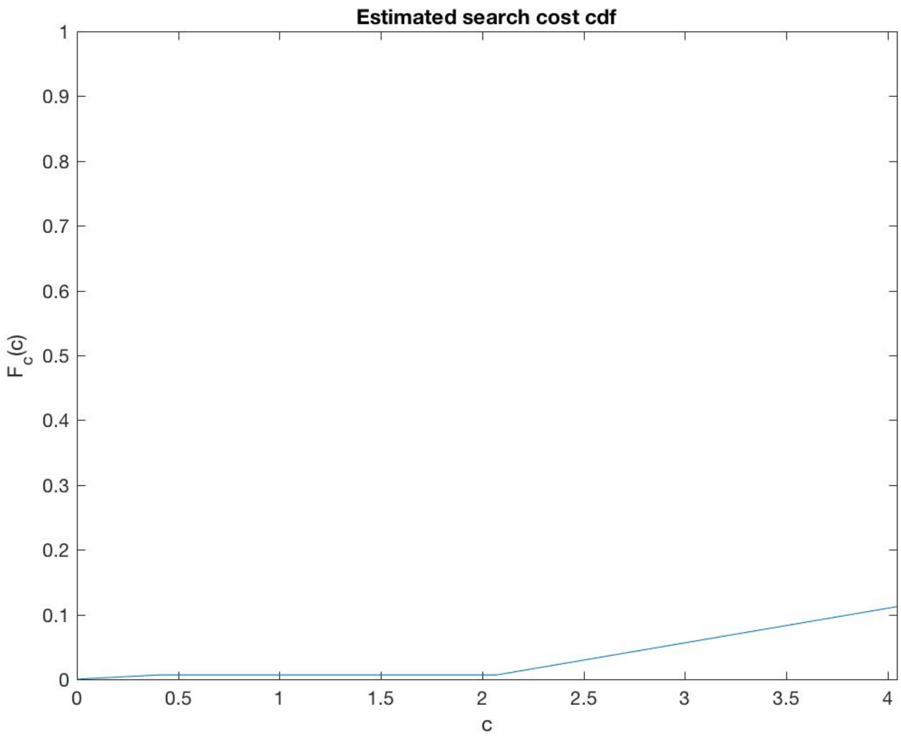
3.3 Two-year


Estimated search cost cdf
$F_c(c)$
c
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.5
1
1.5
2
2.5
3

3.4 One-year

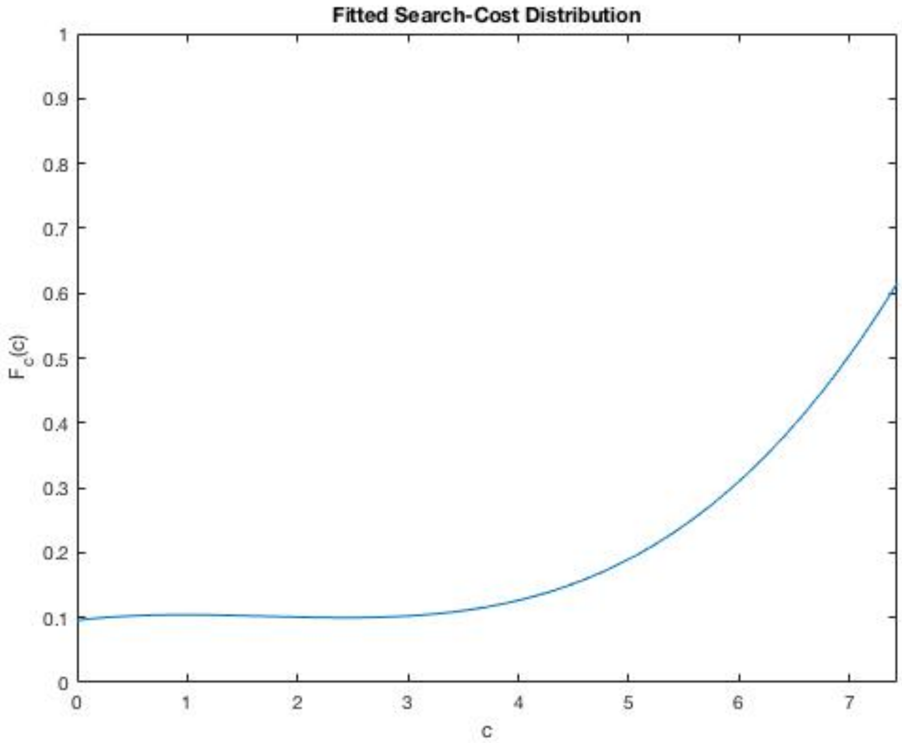


3.5 Three-months

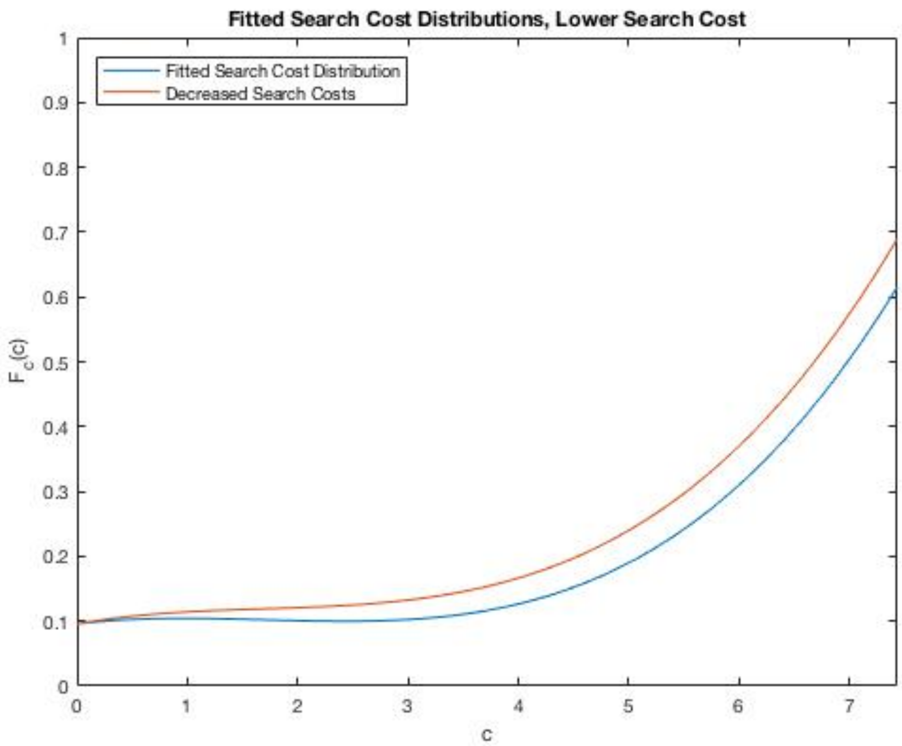


4. Search Cost Distributions

4.1 Fitted search cost distribution, Five-year fixed mortgage rate



4.2 A Change in the Search Costs Distribution



5. Test for Time Trends

Linear regression

Five-year	Estimate	SE	tStat	pValue
Intercept	2.1168	0.027947	75.746	0.0000
Slope	-0.0076742	0.004504	-1.7039	0.092385

Three-year	Estimate	SE	tStat	pValue
Intercept	1.6858	0.020342	82.87	0.0000
Slope	-0.0060909	0.0032784	-1.8579	0.06696

Two-year	Estimate	SE	tStat	pValue
Intercept	1.6792	0.018954	88.591	0.0000
Slope	-0.0099394	0.0030547	-3.2538	0.0016847

One-year	Estimate	SE	tStat	pValue
Intercept	1.6416	0.021174	77.528	0.0000
Slope	-0.0029924	0.0034125	-0.8769	0.38323

Three-months	Estimate	SE	tStat	pValue
Intercept	1.5714	0.017263	91.028	0.0000
Slope	-0.00055303	0.0027822	-0.19877	0.84296

6. Test for Auto Correlation

Five-year	IF = 1, then significant	IF = 0, then insignificant						
Num. of lags	Bank Danske Bank	Handels banken	Länsförs äkringar	Nordea	SBAB	SEB	Skandia banken	Swedbank
0	1	1	1	1	1	1	1	1
1	1	0	0	0	0	1	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0

Three-	IF = 1, then significa	IF = 0, then insignifi

year	nt	cant						
Num. of lags	Bank Danske Bank	Handels banken	Länsförs äkringar	Nordea	SBAB	SEB	Skandia banken	Swedba nk
0	1	1	1	1	1	1	1	1
1	0	0	0	0	0	1	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0

Two-year	IF = 1, then significa nt	IF = 0, then insignifi cant						
Num. of lags	Bank Danske Bank	Handels banken	Länsförs äkringar	Nordea	SBAB	SEB	Skandia banken	Swedba nk
0	1	1	1	1	1	1	1	1
1	0	0	0	1	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0

One year	IF = 1, then significa nt	IF = 0, then insignifi cant						
Num. of lags	Bank Danske Bank	Handels banken	Länsförs äkringar	Nordea	SBAB	SEB	Skandia banken	Swedba nk
0	1	1	1	1	1	1	1	1
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0

6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0

Three months	IF = 1, then significant	IF = 0, then insignificant						
Num. of lags	Bank Danske Bank	Handels banken	Länsförs äkringar	Nordea	SBAB	SEB	Skandia banken	Swedbank
0	1	1	1	1	1	1	1	1
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0

7. Robustness Check

7.1 Search Cost Distributions, Five Random Banks

Contract lengths	Three-months	One-year	Two-years	Three-years	Five-years
$\underline{I}$	143	135	152	151	191
$\bar{I}$	168	190	174	184	242
N	5	5	5	5	5
M	50	50	46	50	50
q_1	0.57 (0.18)	0.76 (0.14)	0.83 (0.13)	0.54 (0.11)	0.53 (0.21)
q_2	0.16 (0.07)	0.20 (0.10)	0.14 (0.10)	0.39 (0.09)	0.39 (0.10)
q_3	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
q_4	0.27 (0.19)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
q_5	0.00 (0.03)	0.04 (0.04)	0.03 (0.03)	0.07 (0.05)	0.08 (0.12)
r	132.66 (5.30)	64.01 (18.01)	107.86 (9.15)	135.46 (4.10)	168.13 (10.64)
LL	150.62	189.61	146.02	160.30	184.38
KS	0.81 (0)	1.80 (1)	1.24 (0)	1.11 (0)	0.76 (0)

7.2 Critical Search Cost Values, Five Random Banks

Contract lengths	Three-months	One-year	Two-years	Three-years	Five-years
Δ_1	4.44 (0.24)	8.86 (3.50)	3.53 (2.25)	5.13 (0.46)	7.91 (0.89)
Δ_2	2.26 (0.20)	4.45 (1.49)	1.84 (1.03)	2.28 (0.17)	3.51 (0.42)
Δ_3	1.34 (0.25)	2.71 (0.80)	1.14 (0.58)	1.29 (0.09)	1.97 (0.25)
Δ_4	0.88 (0.23)	1.83 (0.49)	0.78 (0.37)	0.85 (0.05)	1.26 (0.17)